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CONSTITUTION

Article I

Name, Object and Location

Name

1. The name of this Association is the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Object

2. Its object is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

Means to be Used

3. The means to be used for this purpose shall be as follows:

(a) Meetings for the reading and discussion of reports and papers and for social intercourse.

(b) Investigation of matters pertaining to the objects of the Association through Standing and Special Committees.

(c) The publication of papers, reports and discussions.

(d) The maintenance of a library.

Responsibility

4. Its action shall be recommendatory, and not binding upon its members.

Location of Office

5. Its permanent office shall be located in Chicago, Illinois, and the annual convention be held in that city.

Article II

Membership

Membership Classes

1. The membership of this Association shall be divided into four classes, viz: Members, Honorary Members, Associates, and Life Members.

Membership Qualifications

2. A Member shall be:

(a) Either a Civil Engineer, a Mechanical Engineer, an Electrical Engineer, or an official of a railway corporation, who has had not less than five (5) years' experience in the location, construction, maintenance or operation of railways, and who, at the time of application for membership, is engaged in railway service in a responsible position in charge of work connected with the Location, Construction, Operation or Maintenance of a Railway, or an Engineering Editor of a Railway Magazine; provided, that all persons who were Active Members prior to March 20, 1907, shall remain Members except as modified by Article II, Clause 9.

(b) A Professor of Engineering in a college of recognized standing.

In determining the eligibility of candidates to the grade of Member, graduation in an engineering school of recognized standing shall be considered as equivalent to three years of active practice, and the satisfactory completion of each year of work in such school without graduation shall be considered as equivalent to one-half year of active practice.

Honorary Membership Qualifications

3. An Honorary Member shall be a person of acknowledged eminence in railway engineering or management. The number of Honorary Members shall be limited to ten.

Associate Membership Qualifications

4. An Associate shall be a person not eligible as a Member, but whose pursuits, scientific acquirements or practical experience qualify him to cooperate with Members in the advancement of professional knowledge, such as Consulting, Inspecting, Contracting, Government or other Engineers, Instructors of Engineering in Colleges of recognized standing, and Engineers of Industrial Corporations when their duties are purely technical.

Life Member

5. A Member who has paid dues for 35 years, or who has reached the age of seventy (70) years and has paid dues for not less than 25 years. Life members shall be exempt from the payment of further dues.

Membership Rights

6. (a) Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights of Members, except that of holding office, and shall be exempt from the payment of dues.

(c) Associates shall have all the rights of Members, except those of voting and holding office.

Age Requirement

7. An applicant to be eligible for membership in any class shall not be less than twenty-five (25) years of age.

"Railway" Defined

8. The word "railway" in this Constitution means one operated by steam or electricity as a common carrier, dependent upon transportation for its revenue. Engineers of street railway systems and of railways which are used primarily to transport the material or product of an industry or industries to and from a point on a railway which is a common carrier, or those which are merely adjuncts to such industries, are eligible only as Associates.

Changes in Classes

9. A Member, elected after March 20, 1907, who shall leave the railway service, shall cease to be a Member, but may retain membership in the Association as an Associate, subject to the provisions of Article II, Clause 9; provided, however, if he re-enters the railway service, he shall be restored to the class of Members.

Supply Men

10. Persons whose principal duties require them to be engaged in the sale or promotion of railway patents, appliances or supplies, shall not be eligible for, nor retain membership in any class in this Association, except that those who were Active Members prior to March 20, 1907, may retain membership as Associates; provided, however, that anyone having held membership in the Association and subsequently having become subject to the operation of this clause, shall, if he again becomes eligible, be permitted to re-enter the Association, without the payment of a second entrance fee.

Transfers

11. The Board of Direction shall transfer members from one class to another, or remove a member from the membership list, under the provisions of this Article.

Article III

ADMISSIONS AND EXPULSIONS

Charter Membership

1. The Charter Membership consists of all persons who were elected before March 15, 1900.

Application for Membership

2. The Charter Membership having been completed, any person desirous of becoming a member shall make application upon the form prescribed by the Board of Direction, setting forth in a concise statement his name, age, residence, technical education and practical experience. He shall refer to at least three members to whom he is personally known, each of whom shall be requested by the Secretary to certify to a personal knowledge of the candidate and his fitness for membership.

Election to Membership

3. Upon receipt of an application properly endorsed, the Board of Direction, through its Secretary, or a Membership Committee selected from its own members, shall make such investigation of the candidate's fitness as may be deemed necessary. The Secretary will furnish copies of the information obtained and of the application to each member of the Board of Direction. At any time, not less than thirty days after the filing of the application, the admission of the applicants shall be canvassed by letter-ballot among the members of the Board, and affirmative votes by two-thirds of its members shall elect the candidate; provided, however, that should an applicant for membership be personally unknown to three members of the Association, due to residence in a foreign country, or in such a portion of the United States as precludes him from a sufficient acquaintance with its members, he may refer to well-known men engaged in railway or allied professional work, upon the form above described, and such application shall be considered by the Board of Direction in the manner above set forth, and the applicant may be elected to membership by a unanimous vote of the Board.

Subscription to Constitution

4. All persons, after due notice from the Secretary of their election, shall subscribe to the Constitution on the form prescribed by the Board of Direction. If this provision be not complied with within six months of said notice, the election shall be considered null and void.

Reinstatement

5. Any person having been a member of this Association, and having, while in good standing, resigned such membership, may be reinstated without the payment of a second entrance fee; provided his application for reinstatement is signed by five members certifying to his fitness for same, and such application is passed by a two-thirds majority of the Board of Direction.

Honorary Membership

6. Proposals for Honorary Membership shall be submitted by ten or more Members. Each member of the Board of Direction shall be furnished with a copy of the proposal, and if, after thirty days, the nominee shall receive the unanimous vote of said Board, he shall be declared an Honorary Member.

Expulsions

7. When charges are preferred against a Member in writing by ten or more Members, the Member complained of shall be served with a copy of such charges, and he shall be called upon to show cause to the Board of Direction why he should not be expelled from the Association. Not less than thirty days thereafter a vote shall be taken on his expulsion, and he shall be expelled upon a two-thirds vote of the Board of Direction.

Resignations

8. The Board of Direction shall accept the resignation, tendered in writing, of any Member whose dues are fully paid up.

Article IV

DUES

Entrance Fee

1. An entrance fee of $10.00 shall be payable to the Association through its Secretary with each application for membership; and this sum shall be returned to the applicant if not elected.

Annual Dues

2. *The annual dues are $10.00, payable during the first three months of the calendar year.

Arrears

3. Any person whose dues are not paid before April 1st of the current year shall be notified of same by the Secretary. Should the dues not be paid prior to July 1st, the delinquent Member shall lose his right to vote. Should the dues remain unpaid October 1st, he shall be notified on the form prescribed by the Board of Direction, and he shall no longer receive the publications of the Association. If the dues are not paid by December 31st, he shall forfeit his membership without further action or notice, except as provided for in Clause 4 of this Article.

Remission of Dues

4. The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member who, from ill-health, advanced age or other good reasons, is unable to pay them.

Article V

OFFICERS

Officers

1. The officers of the Association shall be Members and shall consist of:

A President,
A First Vice-President,
A Second Vice-President,
A Treasurer,
A Secretary,
Nine Directors,

who, together with the five latest living Past-Presidents who are Members, shall constitute the Board of Direction in which the government of the Association shall be vested, and who shall act as Trustees, and have the custody of all property belonging to the Association.

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* The annual payment of $10.00 made by each member is to be sub-divided and credited on the books of the Association, as follows: To member's subscription to the Bulletin, $5.00; annual dues, $5.00.

Vice-Presidents' Priority

2. The offices of First and Second Vice-President shall be determined by the priority of their respective dates of election.

Terms of Office

3. The terms of office of the several officers shall be as follows:

President, one year.
Vice-Presidents, two years.
Treasurer, one year.
Secretary, one year.
Directors, three years.

Officers Elected Annually

4. (a) There shall be elected at each Annual Convention:

A President,
One Vice-President,
A Treasurer,
A Secretary,
Three Directors.

(b) The candidates for President and for Vice-President shall be selected from Past or Present members of the Board of Direction.

Conditions of Re-election of Officers

5. The office of President shall not be held twice by the same person. A person who shall have held the office of Vice-President or Director shall not be eligible for re-election to the same office until at least one full term shall have elapsed after the expiration of his previous term of office.

Term of Officers

6. The term of each officer shall begin with his election and continue until his successor is elected.

Vacancies in Offices

7. (a) A vacancy in the office of President shall be filled by the First Vice-President.

(b) A vacancy in the office of either of the Vice-Presidents shall be filled by the Board of Direction by election from the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) Any other vacancies for the unexpired term in the membership of the Board of Direction shall be filled by the Board.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office he is holding; provided, however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provision of Article V, Clause 5.

Vacation of Office

8. When an officer ceases to be a Member of the Association, as provided in Article II, his office shall be vacated, and be filled as provided in Article V, Clause 7.

Disability or Neglect

9. In case of the disability or neglect in the performance of his duty of an officer, the Board of Direction, by a two-thirds majority vote of the entire Board, shall have power to declare the office vacant, and fill it as provided in Article V, Clause 7.

Article VI

NOMINATION AND ELECTION OF OFFICERS

Nominating Committee

1. (a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members and five Members not officers.

(b) The five Members shall be elected annually when the officers of the Association are elected.

Number of Candidates

2. It shall be the duty of this Committee to nominate candidates to fill the offices named in Article V, and vacancies in the Nominating Committee caused by expiration of term of service, for the ensuing year, as follows:

Office to be Filled	*Number of Candidates to be named by Nominating Committee.*	*Number of Candidates to be Elected at Annual Election of Officers.*
President	1	1
Vice-President	1	1
Treasurer	1	1
Secretary	1	1
Directors	9	3
Nominating Committee	10	5

Chairman

3. The Senior Past-President shall act as permanent chairman of the Committee, and will issue the call for meetings. In his absence from meetings, the Past-President next in age of service shall act as Chairman pro tem, at the meeting.

Meeting of Committee

4. Prior to December 1st each year, the Chairman shall call a meeting of the Committee at a convenient place and, at this meeting, nominees for officers shall be agreed upon.

Announcement of Names of Nominees

5. The names of the nominees shall be announced by the permanent Chairman to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

Additional Nominations by Members

6. At any time between January 1st and February 1st, any ten or more Members may send to the Secretary additional nominations for the ensuing year signed by such Members.

Vacancies in List of Nominees

7. If any person so nominated shall be found by the Board of Direction to be ineligible for the office for which he is nominated, or should a nominee decline such nomination, his name shall be removed and the Board may substitute another one therefor; and may also fill any vacancies that may occur in this list of nominees up to the time the ballots are sent out.

Ballots Issued

8. Not less than thirty days prior to each Annual Convention, the Secretary shall issue *a ballot* to each voting member of record in good standing, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee, and the ballot shall be accompanied by a statement giving for each candidate his record of membership and activities in this Association.

Substitution of Names

9. Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

Ballots

10. (a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and may substitute another, at any time before the polls close.

Invalid Ballots

11. Ballots not endorsed or from persons not qualified to vote shall not be opened; and any others not complying with the above provisions shall not be counted.

Closure of Polls

12. The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by three tellers appointed by the Presiding Officer. The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

Requirements for Election

13. The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

Tie Vote

14. In case of a tie between two or more candidates for the same office, the members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

Announcement

15. The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

First Nominating Committee

16. Except as to the Past-Presidents, the first Nominating Committee and the three additional Directors provided for shall be appointed by the Board of Direction, one of the Directors for one year, one for two years and one for three years.

Article VII

MANAGEMENT

Duties of President

1. (a) The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio member of all Committees, except the Nominating Committee.

(b) The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and discharge his duties in case of a vacancy in his office.

Duties of Treasurer

2. The Treasurer shall receive all moneys and deposit same in the name of the Association, and shall receipt to the Secretary therefor. He shall invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. He shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

Duties of Secretary

3. The Secretary shall be, under the direction of the President and Board of Direction, the Executive Officer of the Association. He shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. He shall see that the moneys due the Association are collected and without loss transferred to the custody of the Treasurer. He shall personally certify to the accuracy of all bills of vouchers on which money is to be paid. He is to conduct the correspondence of the Association and keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

Auditing of Accounts

4. The accounts of the Treasurer and Secretary shall be audited annually by a public accountant, under the direction of the Finance Committee of the Board.

Duties of Board

5. The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

Board Meeting

6. The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board.

Board Quorum

7. Seven members of the Board shall constitute a quorum.

Board Committees

8. At the first meeting of the Board after the Annual Convention, the following committees from its members shall be appointed by the President, and shall report to and perform their duties under the supervision of the Board of Direction.

a. Finance Committee of three members.
b. Publication Committee of three members.
c. Library Committee of three members.
d. Outline of Work of Standing Committees of five members.
e. Personnel of Committees of five members.
f. Membership Committee of five members.
g. Manual Committee of six members.

Duties of Finance Committee

9. The Finance Committee shall have immediate supervision of the accounts, and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of moneys and as to other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by previous action and authority of the Board of Direction.

Duties of Publication Committee

10. The Publication Committee shall have general supervision of the publications of the Association.

Duties of Library Committee

11. The Library Committee shall have general supervision of the Library, the property therein, and the quarters occupied by the Secretary; shall make recommendations to the Board with reference thereto, and shall direct the expenditure for books and other articles of permanent value, from such sums as may be appropriated for these purposes.

Duties of Committee on Outline of Work of Standing Committees

12. The Committee on Outline of Work of Standing Committees shall present a list of subjects for committee work during the ensuing year at the first meeting of the Board of Direction after the Annual Convention.

Duties of Committee on Personnel

13. The Committee on Personnel shall present a list of Chairmen, Vice-Chairmen and members of Standing Committees for the ensuing year at the first meeting of the Board of Direction after the annual convention.

Duties of Membership Committee

14. The Membership Committee shall make such investigation of applicants for membership as may be deemed necessary and make recommendations to the Board of Direction.

Duties of Committee on Manual

15. The Committee on Manual shall have general supervision of the preparation and issuance of the Manual.

Standing Committees

16. The Board of Direction may appoint such Standing Committees as it may deem best, to investigate, consider and report upon questions pertaining to railway location, construction or maintenance.

Special Committees

17. Special Committees to examine into and report upon any subject connected with the objects of this Association may be appointed from time to time by the Board of Direction.

Discussion by Non-Members

18. The Board of Direction may invite discussions of reports from persons not members of the Association.

Sanction of Act of Board

19. An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next Annual Convention of the Association shall be deemed to be the act of the Association, and shall not afterwards be impeached by any Member.

Article VIII

MEETINGS

Annual Convention

1. The annual convention shall be held in the City of Chicago. The meetings shall begin on a Tuesday in the month of March, as may be determined by the President.

Special Meetings

2. Special meetings of the Association may be called by the Board of Direction, and special meetings shall be so called by the Board upon request of thirty Members, which request shall state the purpose of such meeting. The call for such meeting shall be issued not less than ten days in advance, and shall state the purpose and place thereof, and no other business shall be taken up at such meeting.

Notification of Annual Convention

3. The Secretary shall notify all members of the time and place of the Annual Convention of the Association at least thirty days in advance thereof.

Association Quorum

4. Twenty-five Members shall constitute a quorum at all meetings of the Association.

Order of Business

5. (a) The order of business at annual conventions of the Association shall be as follows:

Reading of Minutes of last meeting.
Address of the President.
Reports of the Secretary and Treasurer.
Reports of Standing Committees.
Reports of Special Committees.
Unfinished business.
New business.
Election of officers.
Adjournment.

(b) This order of business, however, may be changed by a majority vote of members present.

Rules of Order

6. The proceedings shall be governed by "Robert's Rules of Order," except as otherwise herein provided.

Discussion

7. Discussion shall be limited to members and to those invited by the presiding officer to speak.

Article IX

AMENDMENTS

Amendments

1. Proposed amendments to this Constitution shall be made in writing and signed by not less than ten Members, and shall be acted upon in the following manner:

The amendments shall be presented to the Secretary, who shall send a copy of same to each member of the Board of Direction as soon as received. If at the next meeting of the Board of Direction a majority of the entire Board are in favor of considering the proposed amendments, the matter shall then be submitted to the Association for letter-ballot, and the result announced by the Secretary at the next Annual Convention. In case two-thirds of the votes received are affirmative, the amendments shall be declared adopted and become immediately effective.

GENERAL INFORMATION

(Subject to change from time to time by Board of Direction)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS

(A) Appointment of Committees and Outline of Work

Standing Committees

1. The following are Standing Committees:

I. Roadway.
II. Ballast.
III. Ties.
IV. Rail.
V. Track.
VI. Buildings.
VII. Wood Bridges and Trestles.
VIII. Masonry.
IX. Highways.
X. Signals and Interlocking.
XI. Records and Accounts.
XII. Rules and Organization.
XIII. Water Service, Fire Protection and Sanitation.
XIV. Yards and Terminals.
XV. Iron and Steel Structures.
XVI. Economics of Railway Location.
XVII. Wood Preservation.
XVIII. Electricity.
XX. Uniform General Contract Forms.
XXI. Economics of Railway Operation.
XXII. Economics of Railway Labor.
XXIII. Shops and Locomotive Terminals.
XXV. Waterways and Harbors.
XXVI. Standardization.
XXVII. Maintenance of Way Work Equipment.

Special Committees

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Clause 14, of the Constitution.

The following are Special Committees:

Stresses in Railroad Track.
Clearances.
Waterproofing of Railway Structures.
Economics of Bridges and Trestles.
Complete Roadway and Track Structure.
Live Load and Impact.

Personnel of Committees

3. The personnel of all Committees will continue from year to year, except when changes are announced by the Board of Direction. Ten per cent of the membership of each Committee shall be changed each year.

Members of Committees who do not attend meetings of Committees during the year or render service by correspondence will be relieved and the vacancies filled by the Board at the succeeding Annual Convention.

Outline of Work

4. As soon as practicable after January 1st of each year the Board of Direction will assign to each Committee the important questions which, in its judgment, should

preferably be considered during the current year. Committees are privileged to present the results of any special study or investigation they may be engaged upon or that may be considered of sufficient importance to warrant presentation.

(B) PREPARATION OF COMMITTEE REPORTS

General

5. The collection and compilation of data and subsequent analysis in the form of arguments and criticism is a necessary and valuable preliminary element of committee-work.

Collection of Data

6. Committees are privileged to obtain data or information in any proper way. If desired, the Secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

Plan of Reports

7. Committee reports should be prepared as far as practicable to conform to the following general plan:

(a) It is extremely important that every Committee should examine its own subject-matter in the Manual prior to each Annual Convention, and revise and supplement it, if deemed desirable, giving the necessary notice of any recommended changes in accordance with Clause 6 (a) of the General Rules for the Publication of the Manual. If no changes are recommended, statement should be made accordingly.

(b) When deemed necessary, the previous report should be reviewed.

(c) Subjects presented in previous reports on which no action was taken should be resubmitted, stating concisely the action desired. It may not be necessary to repeat the original text in the report, reference to former publication being sufficient, unless changes in the previously published version are extensive. Minor changes can be explained in the text of the report.

Definitions

(d) Technical terms used in the report, the meaning of which is not clearly established, should be defined, but defined only from the standpoint of railway engineering.

History

(e) If necessary, a brief history of the subject-matter under discussion, with an outline of its origin and development, should be given.

Analysis

(f) An analysis of the most important elements of the subject-matter should be given.

Argument

(g) The advantages and disadvantages of the present and recommended practices should be set forth.

Illustrations

(h) Illustrations accompanying reports should be prepared so that they can be reproduced on one page. The use of folders should be avoided as much as possible, on account of the increased expense and inconvenience in referring to them. Plans showing current practice, or necessary for illustration are admissible, but those showing proposed definite design or practice should be excluded. Recommendations should be confined to governing principles.

Illustrations should be made on tracing cloth with heavy black lines and figures, so as to stand a two-thirds reduction; for example: To come within a type page (4 inches by 7 inches), the illustration should be made three times the above size.

To insure uniformity, the one-stroke, inclined Gothic lettering is recommended.

Photographs should be clear and distinct silver prints.

Conclusions

(i) The conclusions of the Committee which are recommended for publication in the Manual should be stated in concise language, logical sequence, and grouped together, setting forth the principles, specifications, definitions, forms, tables and formulas included in the recommendation. Portions of the text of the report which are essential to a clear interpretation and understanding of the conclusions, should be included as an integral part thereof.

(C) Publication of Committee Reports

Reports Required

8. (a) Reports will be required from each of the Standing and Special Committees each year.

(b) Although several subjects may be assigned to each Committee by the Board of Direction, a full report on only one subject is expected at each Annual Convention, but the preliminary work on some of the remaining subjects should be in progress, and, when deemed advisable, partial reports of progress should also be presented. This method allows time for their proper preparation and consideration.

Date of Filing Reports

9. Committee reports to come before the succeeding convention for discussion should be filed with the Secretary not later than November 1st of each year.

10. Committees engaged upon subjects involving an extended investigation and study are privileged to present progress reports, giving a brief statement of the work accomplished, and, if deemed expedient, a forecast of the final report to be presented.

Publication of Reports

11. Committee reports will be published in the Bulletin in such sequence as the Board of Direction may determine, for consideration at the succeeding convention. Reports will be published in the form presented by the respective Committees. Alterations ordered by the convention will be printed as an appendix to the report.

Written Discussions

12. Committees should endeavor to secure written discussions of published reports. Written discussions will be transmitted to the respective Committees, and if deemed desirable by the Committee, the discussions will be published prior to the convention and be considered in connection with the report.

Verbal Discussions

13. Each speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(D) CONSIDERATION OF COMMITTEE REPORTS

Sequence

14. The sequence in which Committee reports will be considered by the convention will be determined by the Board of Direction.

Method

15. The method of consideration of Committee reports will be one of the following:

(a) Reading by title.
(b) Reading, discussing and acting upon each conclusion separately.
(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

Final Action

16. Action by the convention on Committee reports will be one of the following, after discussion is closed:

(a) Receiving as information.
(b) Receiving as a progress report.
(c) Adoption of a part complete in itself and referring remainder back to Committee.
(d) Adoption as a whole.
(e) Recommittal with or without instructions.
(f) Adoption as a whole.
(g) Recommendation to publish in the Manual.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the Committee considers affected.

The Chair will decline to entertain amendments which in his opinion lie entirely within the duties of the Editor.

(E) PUBLICATION OF ABSTRACTS BY TECHNICAL JOURNALS

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the Bulletin; provided, application therefor is made in writing and proper credit be given the Association, authors or Committees presenting such material.

GENERAL RULES FOR THE PUBLICATION OF THE MANUAL

Title

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall edit the Manual and shall have authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Adoption of Reports Not Binding

3. Matters adopted by the Association and subsequently published in the Manual shall be considered in the direction of good practice, but shall not be binding on the members.

Contents

4. The Manual will only include conclusions relating to definitions, specifications and principles of practice as have been made the subject of a special study by a Standing or Special Committee and embodied in a Committee report, published not less than thirty days prior to the Annual Convention, and submitted by the Committee to the Annual Convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction, should be reviewed by the Association of American Railroads, may be referred to that Association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the Committee report and subsequent discussion and the final action of the Association.

Revision

6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent Annual Convention, provided such changes are proposed in time for publication not less than thirty days prior to the Annual Convention, and in the following manner: (a) Upon recommendation of the Committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. The Manual will be revised either by publishing a new edition or a supplemental pamphlet as promptly as possible after each Annual Convention.

PROCEEDINGS

The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction and maintenance of Railways. Its action is not binding upon its members.

TUESDAY, MARCH 10, 1936

MORNING SESSION

The Thirty-Seventh Annual Convention of the American Railway Engineering Association was called to order in the Grand Ball Room of the Palmer House, Chicago, Illinois, by the President, Mr. Robert H. Ford, Assistant Chief Engineer, Chicago, Rock Island & Pacific Railway.

The President:—The convention will come to order. This is the Thirty-seventh Annual Meeting of the American Railway Engineering Association. It is now declared open for the transaction of business. This meeting is also the annual session of the Construction and Maintenance Section, Division IV—Engineering, of the Association of American Railroads, the meetings being concurrent.

Will the Board of Direction please come to the platform?

The first order of business is the reading of the Minutes of the last annual meeting. Inasmuch as these Minutes have been printed and a copy furnished to each member, unless there is objection, the reading of the Minutes will be dispensed with. As there is no objection, the Minutes stand approved as printed.

The next order of business is the President's Address.

ADDRESS OF PRESIDENT ROBERT H. FORD

It is customary at this time for the President to give an account of principal events affecting the American Railway Engineering Association since the previous convention, and to make any recommendations which he feels the circumstances justify.

The past year has been one of constructive work. It has been made so by that same spirit of helpfulness and sympathetic cooperation that continue to exist between the Board of Direction and its administrative officers on the one hand, and the Chairmen of Committees and members of your Association on the other.

It is a privilege as well as a real pleasure to report to you that without a single exception all of your officers have been active and have loyally and intelligently promoted the same character of work which has advanced the Association to the enviable position which it now holds in transportation engineering with the railways and the public generally.

During the year there have been increasing evidences of opportunities for greater service by this Association. Such opportunities should prove helpful to our members because they provide additional means for a more liberal education with corresponding benefits.

Our membership shows an increase; although small, it is nevertheless, indicative of a healthier tone in engineering, construction, and maintenance among the railroads. It is also an evidence of continued confidence in the value of the work being done by this Association.

We have no debts. There is a substantial reserve. The wise financial policy of our predecessors has been continued.

Where financial assistance has become necessary for the work of Committees, contributions have been obtained in some cases from the Association of American Railroads, who have generously aided us to carry out our research studies and investigations.

In other cases the Association has been able to carry on supplemental work by what might be termed the pooling of facilities and brains, between the agencies of the railroads represented by the proper Committees of this Association and generally similar representatives from some of the major industries.

In other instances efforts have been directed to the establishment of suitable contacts with various organizations with a view of obtaining desired information by our Committees without duplication of effort or needless expense. This has, to some extent, been made possible by better collaboration between Committees of this Association and corresponding committees of the American Society for Testing Materials, the American Society of Civil Engineers, and various scientific research organizations of the Federal Government, and similarly with the various Divisions of the Association of American Railroads, notably the Mechanical Division. The Committee on Standardization under the leadership of E. M. Hastings, Chief Engineer, Richmond, Fredericksburg & Potomac Railroad, has been especially helpful in this direction.

Important contributions to the Science of Engineering have been made during the year. Perhaps the most important are the Specifications for the Design of Steel Railway Bridges and Concrete Railway Structures, which were published by this Association under the auspices of the Association of American Railroads. This book consisting of 260 pages was prepared to meet the increasing need of a standardized work on bridge design and construction. It has been most favorably received by public authority and the engineering profession generally, and has been accorded a place among standard technical publications in the United States.

Committees VIII and XV collaborated in the preparation of this work. The Board of Direction wishes to acknowledge and thank the Chairmen of these Committee , Messrs. Haggander and Hirschthal, and their immediate associates, Messrs. Dalstrom, Selby, Simmons, and Lacher, and others of these Committees who devoted such a vast amount of time and effort to this notable work.

Manual.—The revision of the Manual has been actively continued during the year. It will be published as soon as possible after the Annual Meeting. It will contain approximately 1,850 pages, and represents 37 years of intelligent work and the sustained efforts of thousands of earnest Engineers. It is of interest to note that the work of this Association is expressed in 38,600 pages of prepared reports and 4600 pages of discussion at annual conventions. From this Manual has been issued a code which represents up to-date, uniform practices on all phases of problems concerned with railway transportation engineering.

This work is under the direction of a committee of Past-Presidents, with John E. Armstrong as Chairman, and D. J. Brumley, Editor and Consultant, the main committee being aided by a special committee from the membership, composed of men of recognized ability and qualifications.

It is not difficult to predict that the Manual of this Association, when completed and published, will easily take front rank among standard engineer encyclopedia. It will be an outstanding monument to the men serving on these two committees, and to its able and versatile Editor, D. J. Brumley.

A particularly fine example of experimental research work of great value to the railroads and the public generally is the contribution of J. B. Hunley, Engineer of Bridges and Structures of the Big Four Railroad, the results being published by this Association in October 1935 as Bulletin 380.

Approximately 13 per cent of the roadway investment of the railroads, equivalent to about three billion dollars, is in bridges. In designing bridges an amount of metal must be added to take up the shock on the bridge which results from moving trains. This is known as Impact.

Originally the allowance for Impact was based upon arbitrary determinations as a result of incomplete data upon which to base conclusions. By the application of more scientific methods it has become increasingly evident that large savings are possible both by reducing and/or reapportioning the amount of metal which under present practice is being put into bridges or by extending the service life of existing bridges.

The railways annually expend approximately twenty-three million dollars for bridges, of which eleven million dollars is for new structures and twelve million dollars is for replacement of light bridges. Committee XV—Iron and Steel Structures, estimates that, based upon data and results already obtained, a saving of about two million annually could be made if they had at their command the necessary scientific data of the true effect of *Impact* on railway bridges.

The Committee estimates that it will require about three years to complete this study. The Board of Direction is hopeful of being able to obtain a modest annual appropriation for this period in order to permit Committee XV to continue and complete this highly important work.

Rail.—The work of the Rail Committee is well-known to you. In many ways it is engaged on some of the most important problems of research thus far undertaken through the joint efforts of the railway and steel industry; by the Engineers of this Association for the railways, and technical committees for the steel companies.

Twenty-eight years have been spent on this problem, but only those closely familiar with the story can grasp the revolutionary changes in the art of rail design and steel rail manufacture that has come during this period. This desirable achievement can be credited to the splendid and cooperative work done by users and manufacturers of steel rails, as well as the wise policy of former President R. H. Aishton of the American Railway Association, which is being continued by its successor, the Association of American Railroads, under the direction of President Pelley and Vice-President Symes.

The research work of Committee IV has been conducted for many years under the able leadership of Earl Stimson, Chief Engineer Maintenance of the Baltimore & Ohio Railroad and his associates, to whom both the steel and rail industries owe a deep debt of gratitude for the constructive work which has been accomplished by them.

Transverse Fissures.—Research work in the troublesome and complicated problem of transverse fissures is also under investigation by Committee IV, who are working jointly with the rail manufacturers' technical committee and the Engineering Experiment Station of the University of Illinois, the latter being in charge of Research Professor H. F. Moore. Some especially interesting and valuable research work of a high character has been done. The cost of this investigation to date has been approximately $200,000, contributed equally by the users and manufacturers. The purpose of this monumental work is to discover the cause of transverse fissures and to devise a remedy therefor. It is another example of intensive original research work, the results of which will have a material bearing on freeing the railways from the menace of failed rails due to transverse fissures.

As would be expected, Railway Engineers in particular are deeply interested in this problem, and I feel that it is only proper that this Association be advised that a lasting debt of gratitude is also due to Messrs. Aishton and Gormley, whose driving forces and initiative have been so helpful in the inauguration and continuation of this work. Our Board and the Rail Committee have the interest and enthusiasm, and the Association of

American Railroads have generously agreed to supply the necessary contribution requested for a continuation of this work, so important alike to the railways and the steel industry.

Stresses in Railroad Track.—For years very little has been actually known of the action and resulting strengths developed in the various parts of the railway subgrade and track structure under passing train loads running at high, moderate, and low speeds. It was known, however, that in combination these little understood forces exert a powerful effect on railway maintenance and renewal costs, and doubtless influence safety in operation as well.

The application and final identification of these forces may ultimately result in revolutionary changes in the track structure, which will render it capable of sustaining moving train loads at very greatly increased speeds. In any event it is apparent that the results of this increased knowledge will greatly increase the ability of our Engineers to design and construct a better and more economically maintained track structure.

The work is being conducted under a nationally known scientist, Dr. A. N. Talbot, Professor-Emeritus of the University of Illinois and a former Director of this Association. Dr. Talbot is supported by a selected personnel of qualified Engineers and scientists from among the members of this Association. The Committee is being aided by a highly skilled group from the staff and graduate students of the University of Illinois.

This research work should also prove of great value in connection with future studies on locomotive counterbalancing, which your Board and the Special Committee are hopeful may soon be jointly inaugurated with the Mechanical Division.

The railroads and this Association owe a deep debt of gratitude to Dr. Talbot and this splendid Committee for the monumental work that has been accomplished.

May I diverge for the moment to say that the work of Dr. Talbot began over fifteen years ago and has been continued all these years for the pure joy of accomplishment. He has not been given, nor indeed has he asked, one cent for all the time and effort so generously given to this great work.

Boiler Feed Water.—Another piece of research work of more than ordinary importance has been undertaken by the Water Service Committee, No. XIII. It concerns the exploration and scientific examination into the subject of boiler feedwater. The railroads use more water for boiler purposes than any other major industry. Because of the conditions under which locomotives must operate, boiler water conditioning is correspondingly of greater importance for efficient and economical railway operation.

All natural waters carry impurities. The effects of these impurities in the water are pitting, corrosion, scale formation, embrittlement or cracking of steel, and foaming and priming of boilers.

In addition to the normal savings being made currently, the Committee reports that annual savings of not less than twelve million dollars can be made by improved methods for properly conditioning water to make it suitable for boiler purposes. Indeed, some authorities have placed this saving as high as forty million dollars annually.

Other major industries are similarly affected although not to the same extent as the railroads. Authoritative data is not available of the cause and effect or the proper means for correction.

There are few subjects within the field of Transportation Engineering that offer more productive possibilities for economy in railway operation or more benefits for the railway as a whole than a scientific study of boiler feedwater.

This work is being conducted by a man of scientific attainments of high order and a recognized authority on the subject, R. C. Bardwell, Chairman of Committee XIII—Water Service, and Superintendent of Water Supply of the Chesapeake & Ohio Railway, supported by a strong personnel of scientists and chemists among the membership of this Association, and in collaboration with other scientific groups with similar objectives.

The investigation of boiler feedwater has been seriously handicapped by a lack of funds. The Board of Direction, however, is fully alive to the importance of this subject and is hopeful that sufficient funds may soon be made available and that the work may proceed advantageously.

General.—I have selected these few cases as typical examples of many other important subjects upon which your Committees are engaged, in order that you may perhaps have a better realization of the practical accomplishments of this Association as well as to indicate something of the value of its work to the Transportation Industry and to Engineers generally. It has been largely due to the close cooperation between the railway and university personnel that this Association has been able to accomplish such excellent results.

The American Railway Engineering Association is an organization of some two thousand Engineers who are concerned with the scientific development of Transportation Engineering on the railways of the United States and its possessions, Canada, and more than twenty other countries. For nearly forty years this Association has engaged in vast research undertakings in the field of Railway Transportation, largely through the agency of volunteer committees that have worked for the pure joy of accomplishment rather than for personal aggrandizement.

This Association was organized by a few earnest men of scientific attainment who banded together for the solution of common problems by the assembling of pertinent, accurate and comprehensive facts. These men seem to have been inspired by the same motives that actuated the founders of the American Constitution. They believed that certain principles are as essential to success in collective action as they are in personal relationships, and that among these were the establishment of confidence by adhering to the precepts of consistency and truth. They decreed, therefore, that the work be so organized and conducted as always to remain free from the dominance and control of any individual or interest. Through all these years this spirit has prevailed, the policies and procedure of the Association being directed by a Governing Board that is charged directly with this responsibility by the Constitution and By-Laws.

There have been times in the Association's history when, for the moment, expediency seemed to demand a departure from the original scheme, but the policy of the founders has prevailed, for reasons that were so well stated nearly twenty years ago by former President Charles A. Morse, and overwhelmingly supported by a referendum of the membership at the time. Speaking for the Governing Board, Mr. Morse expressed the belief that more valuable results can be secured by an association composed of individual members who are free to give expression to their beliefs, because, as he pointed out, the engineering mind must be free in its research work and therefore must be adaptable to changing conditions.

The standing committees of this Association are continued from year to year, with annual additions and subtractions as the members demonstrate their fitness or fail to do so. It is also the practice in due course to return committee members to the ranks after they have contributed an extended period of service or have become especially informed on certain technics of Transportation Engineering. Thus, through committee service, specific knowledge with respect to recommended practice in the scientific and economic construction, maintenance and operation of railways is made readily available to railway men and public authorities in the territories in which the various members are located.

It has been found by the processes of elimination, education, and rotation that a comprehensive knowledge and a broad vision of the Science of Transportation can be obtained by the rank and file of the membership, and this, in turn, operates to the advantage of the industry as a whole. Additional committee members are recruited annually from the large reservoir of younger men as they evince vision, ability and ambition, that they may avail themselves of the opportunities to develop special proficiency in some one or more of the special fields of activity in Railway Transportation Engineering.

The record of accomplishment of these volunteer workers may not carry with it the stirring appeal to popular imagination that marked the achievements of the pioneer engineers who located and built the railway lines across the pathless wilderness of the West. Nevertheless, it is characterized by the inspiration that prompts the analytical discernment and search for engineering truth and by the desire for attainment for the sheer pleasure that marks the Engineer of comprehending vision.

The Engineer is primarily concerned with the assembly of facts necessary for the solution of definite problems to be analyzed and thereafter interpreted in the light of scientific truth. This is the principle upon which the work of this Association is based. But the fact that the work is conducted through the agency of committees is confusing at times to uninformed persons, who apparently assume that the deliberations of engineering committees are comparable with the work of the usual run of popular committee organizations. This is erroneous, of course. There is no comparison either in the character of purpose or methods of work.

The committee work of this Association embraces two fields of usefulness, each of which presents opportunities for education and the dissemination of knowledge among its members.

The first field deals with the immediate needs of current operating experience, whereby mechanisms and practices within the industry may become increasingly adaptable or efficient, to the end that railway service may, in turn, become increasingly cheaper and better.

The second field is concerned with the application of new or possibly not heretofore applied discoveries in the field of fundamental science, a knowledge of which is inspired by the necessity of producing something that will effect more or less revolutionary changes in existing practices. In a word, it implies the introduction of means for improving transportation service in ways that have not been anticipated by current operating experience.

The collective experience of many students of transportation appears to justify the conclusion that it is usually by a thorough knowledge of the first of these fields of endeavor that the greatest developments have resulted from the second.

While volunteer committees of Engineers may not be able to directly undertake basic research in science or in technology, their practical experience and their appreciation of the problems with which the railroads are confronted make it possible for them to utilize the results of research most effectively.

Conditions, however, largely beyond the control of the railway industry have demanded that it be concerned chiefly with the solution of problems arising out of immediate necessities, largely to the exclusion of exploratory work of the type conducted by other major industries for developments that definitely transcend current needs.

Our Committees do not have at their command the vast financial resources, or the great laboratories manned with highly-trained technical personnel and directed by outstanding scientists, but what may perhaps be of greater significance, they do have available the splendid laboratories and trained personnel of our great universities and the unexcelled opportunities for closer and reciprocal relationships. It is from these same sources that they recruit talent for the upbuilding and renewing of their staffs, after it has been molded and developed, and it is from this same source that our railways and other major industries must draw heavily in the future.

It would appear, then, that in reality the ultimate interest of transportation lies not in a further duplicating of laboratories or of skilled, scientific personnel in separately functioning research departments, but rather with these great training schools of youth, with their splendid equipment and equally able but unfortunately so little known personnel. There is, moreover, a well-defined, although as yet undisclosed common interest which would be fostered and strengthened by some mutually satisfactory plan whereby the work of our voluntary committees will be supplemented, where and to the extent necessary or desirable, by the facilities of these schools and colleges with their strategically located professional and scientific staffs and corps of graduate students. It would appear that many possibilities for the improvement of Transportation Engineering and also of industry generally lie in this direction.

The needs of the present differ widely from those of the past. Owing to the enormous programs of expansion that have been carried out in recent years, the transportation facilities now available greatly exceed the public needs of the present and the immediate future. This points at once to the necessity of focusing the attention of our Engineers for some years to come largely in the direction of the perfection and harmonization of existing agencies, to the end that they will better meet the current operating requirements, rather than on new and extensive projects for increasing traffic capacity. But this does not imply any lessening of the need for research. In fact, it prompts an increased demand, as for example, by better and more skilfully designed mechanisms or facilities, the objective being increased efficiency by the production of operating economies. There is indeed an urgent call for engineering investigations, conducted possibly along a broader scope than heretofore and unfettered by prejudices or preconceived conclusions, that will be fruitful of basic truths concerning the many perplexing difficulties that beset the railways in these trying times.

The Transportation Industry is not greatly in need of new captains and generals, as some would have you believe, but there is always a definite need of the material from which the captains and generals of the future can be developed. Sergeants who can become top-sergeants, with all that the name implies, skilfull corporals, and qualified privates, fortified with adequate knowledge, principally of science, the psychology of human relationships, and the power to think clearly and dispassionately, are the kind of human material that is needed.

May I again point out that it is from the reserves of qualified youth, trained largely in our technical schools and colleges, that the rail industry must draw upon heavily in the future if its mechanism is to be maintained in a manner that would enable the public and the employees to reap the benefits from progress in the arts and sciences, with a defined objective for better and cheaper transportation, coupled with increasing efficiency in those agencies through which these advantages are made available.

As the representative here today of one of the great engineering organizations may I say to you, and especially to you younger members, to your associates, and to the youth in our schools and colleges, that no greater opportunities will ultimately open up for young men of vision and ability than in the mechanism of the transportation industry. Furthermore, there is no greater post-graduate school or opportunity for the attainment of knowledge in the Science of Transportation and the applied sciences, than through voluntary association in organizations similar to the American Railway Engineering Association.

Perhaps I should add, however, that it is only by constant, continuous, and consistent work, intelligently applied, that the reward can come. No man can expect to get more out than he is willing to put in, and this applies with equal force to the work of volunteer associations like the American Railway Engineering Association, as it does for everything else in life.

Related and major industries and the producers of raw and fabricated materials have a stake in the Transportation Industry. Many of these industries have skilfull staffs of trained men of scientific attainments, with facilities for research and for testing and experimentation. As the rails are in many cases principal users of their products it would seem that better and more satisfactory ways should be found for coordinating the efforts of the Engineers of the railways and the scientists and facilities of industry. I confess I am unable to share the fear, sometimes expressed, that seekers of scientific truth, whether they be in the ranks of the producer or the user, will be swerved from definitely planned objectives, which after all are closely in the interests of both. If there are disadvantages in this plan it would seem that the advantages far outweigh them.

At the crest of the Continental Divide in Montana there stands in striking relief against the western sky an heroic bronze statue of that great Railway Engineer, JOHN F. STEVENS. It marks the dramatic discovery of Marias Pass, by means of which the Great Northern Railway was enabled to continue its advance to the Pacific Coast. At Norwich University, in the restful quietness of the beautiful Green Mountains of Vermont, stands another appropriate marker placed by a great railway system in affectionate memory of a New England youth who later became one of the greatest Railway Engineers of all time, MAJOR-GENERAL GRENVILLE M. DODGE, the man who pioneered the Union Pacific across the plains to connect with the Central Pacific Railway and complete the link that joined the East with the West to make the United States of America a practical reality. Again, a few hundred miles distant, in a great railway station in the heart of a great city, in quiet contemplation, as it seems, of the hurrying crowds who daily throng its vast concourse, is another statue of heroic size erected to the memory of another great Engineer, ALEXANDER JOHNSTON CASSATT, who was the projector of the tunnels under the Hudson River, making entrance of the Pennsylvania Railroad into New York a living reality.

These impressive memorials are indicative of similar evidences elsewhere that belie the all-too-common impression of the lack of human interest on the part of great corporations, for in all three of them we find mute testimony of the affectionate appreciation of vast railway systems for the services of great Engineers. All three pay tribute to those qualifications of *foresight, courage, fidelity* and *ability* that played such a vital part in the development of railway transportation on the American continent.

I refer to these great Engineers because they illustrate the rewards of unselfish service for men with vision and courage to think and work, coupled with honesty and fixity of purpose. If a man lacks these attributes he will not amount to much in engineering or engineering associations such as ours. On the other hand, I believe if he possesses some or all of those qualifications or if he can start off with the qualification of common honesty, there is evidence to support the fact that in associations of Engineers of this character there is a marked tendency to stimulate and develop the other qualities in a man if there is anything at all upon which to build.

* * *

And now, my friends, I thank you for having listened to me, and we will proceed with the regular program (Applause).

The President:—The next order of business is the reports of the Secretary and of the Treasurer. Will the Secretary please present these reports?

REPORT OF THE SECRETARY

March 1, 1936.

To the Members:

This report relates to the activities of the Association for the past year, grouped under the following headings: Finances, Membership, Committee-Work, Publications, and Miscellaneous.

FINANCES

The Financial Statement for the calendar year ending December 31, 1935, is shown on a following page.

The Budget for 1935, as approved by the Board of Direction, called for an allowance of **$25,364.00** for **Ordinary or Current Expenditures.**

The **Actual Expenditures,** as shown by the Financial Statement, were **$25,311.12.**

The **Estimated Receipts** for 1935, as submitted with the Budget, were **$26,700.00.**

The **Actual Receipts,** as indicated in the Financial Statement, were **$29,001.39.**

The **Excess of Receipts Over Ordinary Disbursements** were **$3,690.27.**

Notwithstanding a material increase in the item of printing due to greater volume over the preceding year, and also increases in a few other items, it is gratifying to report that **our Budget has been balanced.**

At the Board meeting of March 14, 1935, it was voted to employ assistance for the Manual Revision Work. A special appropriation of $5,000.00 for this purpose was made by the Board for the balance of the year 1935. The expenditures chargeable to this work to December 31, 1935, were $4,799.49.

At the meeting of the Board held on December 5, 1935, it was voted to appropriate the sum of $5,000.00 for continuing the Manual Revision Work in 1936.

It will be necessary to draw on the surplus for meeting this extraordinary expenditure of Manual Revision Work, and in addition the cost of reprinting the Manual during the current year must be provided for. The revenues derived from the sale of the publication will be credited to this fund.

MEMBERSHIP

Present Status.—The number of members on the rolls as of March 1, 1936, totalled 1910, as against 1903 a year ago—a slight gain, but nevertheless, a gain. The additions during the year were 138; the losses by death, resignations and dropped were 131.

The past several years have been extremely difficult for many members of the Association, who have found it necessary to relinquish their membership due to reduction in salaries, loss of employment or furloughs. With the return to normal conditions, of which there are numerous indications, the losses in membership will no doubt be fully made up in additions and reinstatements.

The Membership Committee of the Board, with the view of recovering some of the lost ground, has recently made a direct appeal to the general membership, soliciting their cooperation and interest in recouping some of the losses heretofore sustained in the membership rolls. Results are already apparent in new applications and resumptions of affiliation of former members.

It is quite generally realized that the membership of an association is its life-blood. Associations are made up of either companies or corporations concerned with a particular industry; or of an individual membership, composed of persons interested in a specific line or phase of industry. The AREA is of the latter type and is composed of men affiliated principally with the Engineering Department of railways.

A substantial membership carries prestige and engenders confidence. It indicates to the public and to the industry it represents that the association is doing worth-while work, and that it is worthy of attracting and holding a large number of persons. Although an association is limited in membership to the number making up the group the association represents, it is seldom that the saturation point has been reached.

Individual members of the Association can be of material assistance in the effort to increase the membership. A suggestion from a member to a personal friend or to an eligible prospect is frequently all that is necessary to secure a desirable member.

It is confidently believed that a year hence it will be possible to show a substantial addition to the present membership rolls. With the cooperation of the individual members, this expectation can be realized.

"Life Members."—Effective January 1, 1936, the "Life Member" class, provided for in the amendment to the Constitution adopted a year ago, became operative. During the year, a questionnaire was sent to members presumed to be eligible to this class of members, to develop the necessary data on which to base the classification. The replies indicated that 103 members were entitled to be classed as "Life Members," as follows:

R. H. Aishton
F. H. Alfred
C. Frank Allen
F. D. Anthony
Hadley Baldwin
R. J. Arey
R. C. Barnard
G. J. Bell
W. G. Besler
J. C. Beye
M. S. Blaiklock
R. S. Blinn
E. W. Boots
D. J. Brumley
G. W. Feagin
J. C. L. Fish
E. A. Frink
E. H. Fritch
Geo. Gibbs
F. W. Gilcreast
J. E. Greiner
W. W. Gwathmey
W. J. Harahan
F. W. Hawks
V. K. Hendricks
G. D. Hicks
R. L. Huntley
Hans Ibsen
E. L. Ingram
F. H. Neff
W. S. Newhall
F. L. Nicholson
J. N. Ostrom
C. A. Paquette
M. P. Paret
F. M. Patterson
W. D. Pence
E. H. Pfafflin
H. C. Phillips
W. B. Poland
R. O. Rote
A. H. Rudd
H. R. Safford
F. E. Schall

Life Members—Continued

Lincoln Bush
C. H. Byers
J. L. Campbell
W. B. Causey
I. M. Chace
G. C. Cleveland
W. W. Colpitts
T. L. Condron
E. H. Connor
S. E. Coombs
C. J. Coon
J. W. Cowper
W. L. Darling
G. M. Davidson
A. L. Davis
J. R. W. Davis
L. A. Downs
F. O. Dufour
W. H. Elliott

H. S. Jacoby
F. G. Jonah
Richard Khuen
G. H. Kimball
W. S. Kinnear
P. M. LaBach
E. H. Lee
J. R. Leighty
J. S. Lemond
James MacMartin
E. C. Macy
Thomas Maney
B. H. Mann
D. W. McNaugher
Wm. Michel
J. C. Mock
Ralph Modjeski
F. A. Molitor
C. A. Morse

A. D. Schindler
H. B. Seaman
W. L. Seddon
A. K. Shurtleff
W. B. Storey
S. Sugiura
J. G. Sullivan
H. R. Talcott
E. E. R. Tratman
F. E. Turneaure
J. A. L. Waddell
W. A. Wallace
L. W. Wells
Edwin F. Wendt
W. J. Wilgus
W. D. Williams
J. R. Worcester
R. C. Young

Deceased Members.—During the year, the Association has sustained the loss by death of twenty-two valued and loyal members. The list of our departed associates is shown on a following page. Brief comments on the deceased follow:

General W. W. Atterbury, President, Pennsylvania Railroad; an outstanding Railway Executive of the United States. During the World War, General Atterbury held the important post of Director–General of Transportation of the A.E.F. in France.

E. B. Ashby, former Chief Engineer, Lehigh Valley Railroad. Member of the Committee on Rail for many years.

H. E. Barlow, Chief Engineer of the "Omaha" line of the Chicago and Northwestern Railway.

John V. Hanna, Chief Engineer, Kansas City Terminal Railway. Served as Chairman of the Ballast Committee for a number of years.

W. W. Wysor, Chief Engineer, United Railways of Baltimore. An active member of the Committee on Ties.

Charles H. Ewing, President, The Reading Company and the Central Railroad of New Jersey. Mr. Ewing was especially active in the affairs of the Association during its earlier years.

Gustav Lindenthal, one of the foremost Bridge Engineers of his time.

F. C. Shepherd, Consulting Engineer, Boston and Maine Railroad. An authority on timber preservation, and for several years an active and efficient Chairman of the Committee on Wood Preservation.

Col. A. P. Wenzell, Special Engineer, New York Central Lines, Chairman of the Committee on Waterways and Harbors.

F. P. Gutelius, Vice-President, Delaware and Hudson Company, in earlier years Chairman of the Committee on Signs, Fences and Crossings.

Charles A. Wilson, Consulting Engineer, Cincinnati Union Terminal Company. Mr. Wilson was an enthusiastic and loyal member of the Association, attended every annual meeting from the date of its organization to 1935, and was one of its organizers in 1899.

R. A. Tanner, Assistant Engineer, Northern Pacific Railway, a faithful and hardworking member of the Committee on Water Service.

R. P. Eubank, General Real Estate Agent of the Chesapeake and Ohio Railway, an able member of the Committee on Uniform General Contract Forms.

C. S. Sample, Principal Assistant Engineer, Missouri Pacific Railroad, an active member of the Roadway Committee.

H. G. Clark, Executive Assistant to the Trustee, Chicago, Rock Island and Pacific Railway, an active member of the Track Committee.

Deceased Members

E. B. Ashby
Retired Chief Engineer, Lehigh Valley Railroad

General W. W. Atterbury
President, Pennsylvania Railroad

H. E. Barlow
Chief Engineer, Chicago, St. Paul, Minneapolis and Omaha Railway

H. G. Clark
Executive Assistant to Trustee, Chicago, Rock Island and Pacific Railway

R. P. Eubank
General Real Estate Agent, Chesapeake and Ohio Railway

C. H. Ewing
President, Reading Company

F. P. Gutelius
Resident Vice-President, Delaware and Hudson Company

John V. Hanna
Chief Engineer, Kansas City Terminal Railway

C. W. Kelly
Secretary, National Railway Appliances Association

George Kenderdine
Assistant Engineer, Pennsylvania Railroad

K. Kurihara
Superintendent, Central Laboratory, South Manchuria Railway Company

Gustav Lindenthal
Consulting Bridge Engineer

S. A. Roake
Civil Engineer

C. S. Sample
Principal Assistant Engineer, Missouri Pacific Railroad

F. C. Shepherd
Consulting Engineer, Boston and Maine Railroad

E. J. Steinbeck
Civil Engineer

J. L. Suesserott
Division Engineer, Staten Island Rapid Transit Company

R. A. Tanner
Assistant Engineer, Northern Pacific Railway

Col. A. P. Wenzell
Special Engineer, New York Central Lines

C. A. Wilson
Consulting Engineer, Cincinnati Union Terminal Company

W. W. Wysor
Chief Engineer, United Railways and Electric Company

K. Yoshizawa
Railway Department, South Manchuria Railway Company

GEOGRAPHICAL DISTRIBUTION OF MEMBERSHIP

United States and Possessions

Alabama	5
Arizona	3
Arkansas	15
California	49
Colorado	14
Connecticut	21
Delaware	2
District of Columbia	30
Florida	10
Georgia	26
Hawaii	1
Idaho	1
Illinois	287
Indiana	33
Iowa	15
Kansas	30
Kentucky	20
Louisiana	12
Maine	10
Maryland	33
Massachusetts	43
Michigan	43
Minnesota	63
Mississippi	6
Missouri	121
Montana	8
Nebraska	22
New Jersey	34
New Hampshire	4
New Mexico	1
New York	165
North Carolina	17
North Dakota	2
Ohio	150
Oklahoma	7
Oregon	4
Pennsylvania	153
Porto Rico	1
Rhode Island	3
South Carolina	1
South Dakota	1
Tennessee	21
Texas	69
Utah	5
Vermont	8
Virginia	81
Washington	20
West Virginia	23
Wisconsin	11
	1,704

Other Countries

Canada	99
Japan	25
Mexico	13
Brazil	8
India	8
Australia	7
Argentine	6
China	6
Cuba	4
England	4
Manchukuo	4
Union Sov. Soc. Rep.	4
Central America	4
Africa	3
Czecho-Slovakia	2
Switzerland	2
Bolivia	1
Columbia	1
France	1
Germany	1
Scotland	1
Siam	1
Spanish Honduras	1
	206

Personnel of Committees by Railways—1935

	Roadway	Ballast	Ties	Rail	Track	Buildings	Wood Bridges and Trestles	Masonry	Highways	Signals and Interlocking	Records and Accounts	Rules and Organization	Water Service and Sanitation	Yards and Terminals	Iron and Steel Structures	Economics of Railway Location	Wood Preservation	Electricity	Uniform General Contract Forms	Economics of Railway Operation	Economics of Railway Labor	Shops and Locomotive Terminals	Waterways and Harbors	Standardization	Maintenance of Way Work Equipment	Stresses in Railroad Track	Clearances	Waterproofing of Railway Structures	Live Load and Impact	Complete Roadway and Track Structure	Economics of Bridges and Trestles	TOTAL
Akron, Canton & Youngst'n	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Alton	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	1
Ann Arbor	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Atchison, Topeka & Santa Fe	2	1	2	3	3	2	1	1	1	----	----	1	2	----	1	----	2	1	----	----	1	----	----	1	1	----	----	1	1	----	----	28
Atlanta, Birmingham & Coast	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Atlantic Coast Line	1	----	----	1	----	----	----	----	----	----	1	----	----	----	1	----	----	----	----	----	1	----	1	----	----	1	----	----	----	----	----	7
Baltimore & Ohio	1	1	----	2	1	1	----	3	2	1	1	1	1	1	2	----	----	1	1	2	1	1	1	2	----	2	2	----	1	----	----	32
B. & O. Chicago Terminal	----	----	1	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	1	1	----	----	----	----	----	----	----	----	4
Belt Railway	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Bessemer & Lake Erie	1	----	----	----	----	----	----	----	----	----	1	----	----	----	----	1	----	----	----	1	----	----	----	1	----	----	----	----	----	----	----	5
Boston & Maine	2	----	----	1	1	----	----	----	----	----	2	----	----	2	----	----	1	----	----	1	1	----	1	1	1	----	----	----	----	----	----	14
Canadian National	----	----	----	2	3	----	----	1	----	1	1	1	----	----	----	----	1	1	1	3	----	----	----	2	1	----	1	----	----	1	----	20
Grand Trunk Western	1	----	----	----	----	----	----	1	1	----	1	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	1	----	1	7
Canadian Pacific	1	----	----	1	1	----	----	1	----	1	----	1	1	1	1	1	----	----	----	----	----	1	----	----	1	----	1	----	----	----	----	13
Central of Georgia	----	----	1	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	1	----	----	----	----	----	----	----	----	4
Central of New Jersey	----	----	----	----	----	----	----	1	----	----	----	1	----	1	----	----	----	1	1	----	----	----	----	----	----	----	----	----	----	----	----	5
Chesapeake & Ohio	3	3	----	2	4	1	3	3	4	1	4	3	4	1	1	2	----	----	1	4	1	2	----	3	3	----	2	2	1	2	----	60
Chicago & Eastern Illinois	----	----	----	----	----	----	----	----	----	1	----	----	----	----	1	----	----	----	----	1	----	1	----	----	----	----	----	----	----	----	----	4
Chicago & Northwestern	1	----	----	1	1	----	----	----	----	1	1	1	1	----	1	----	----	----	----	1	----	----	----	----	1	----	----	1	1	----	----	12
Chicago & Western Indiana	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	1	1	----	----	----	----	----	----	----	----	3
Chicago, Burlington & Quincy	----	1	2	1	2	----	1	1	1	----	1	1	----	1	1	----	1	----	----	1	1	1	1	----	----	----	1	1	----	----	1	21
Chicago Great Western	----	----	----	----	----	----	1	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Chicago, Indianapolis & Louisville	----	----	----	----	----	----	----	----	----	1	1	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	3
Chi., Mil., St. Paul & Pacific	1	----	----	1	1	----	----	----	2	----	1	1	----	----	----	----	1	----	----	1	1	1	----	----	1	----	----	----	----	----	1	13
Chicago, Rock Is. & Pacific	1	1	1	2	1	2	----	----	2	2	1	----	2	----	1	----	2	----	----	----	----	1	----	1	----	----	----	1	----	----	----	21
Cleveland Union Terminals	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Colorado & Southern	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Columbia & Cowlitz	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Delaware, Lackawanna & Western	----	----	----	2	1	----	----	1	1	----	----	----	1	----	----	----	----	----	1	----	----	1	1	1	1	1	1	----	----	----	----	13
Delaware & Hudson	----	----	----	----	----	----	----	----	----	----	1	----	----	1	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	3
Detroit Rapid Transit	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Detroit & Toledo Shore Line	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Denver & Rio Grande West'n	----	----	----	----	----	----	1	----	----	----	----	1	1	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	1	5
Duluth, Missabe & North'n	1	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	3
Elgin, Joliet & Eastern	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Erie	2	----	----	1	2	1	----	1	2	----	1	----	1	2	1	1	----	2	----	1	1	----	1	1	1	1	1	1	----	----	----	26
Florida East Coast	1	----	----	----	----	----	----	----	1	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	3
Great Northern	1	----	----	----	----	----	1	----	----	----	----	----	1	----	1	----	1	----	----	----	----	1	1	----	----	----	----	----	----	----	1	8
Illinois Central	1	1	1	2	3	1	1	----	2	2	1	3	2	2	----	----	2	3	2	1	2	1	1	2	3	----	1	1	1	----	----	42
Illinois Terminal	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	1
Indianapolis Union	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Interborough Rapid Transit	----	----	----	1	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Johnstown & Stony Creek	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1

Kansas City Southern	1	1	----	1	1	----	----	----	----	----	1	----	2	----	1	----	----	----	----	2	1	----	1	----	----	----	----	----	----	----	----	12
Lake Superior & Ishpeming	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	2
Lehigh Valley	----	----	----	1	----	----	1	1	----	----	----	1	----	----	1	----	----	----	----	----	1	----	----	----	1	----	----	----	----	----	----	7
Louisville & Nashville	1	----	1	1	1	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	1	----	1	----	----	----	----	----	----	----	----	7
Maine Central	1	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2	----	----	----	----	----	----	4
Minneapolis & St. Louis	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	1
Missouri-Kansas-Texas	1	1	1	1	----	1	----	----	1	----	1	----	1	----	1	----	----	----	----	----	1	1	----	1	----	----	1	----	----	----	----	13
Missouri Pacific Lines	----	----	2	----	----	----	----	----	1	2	----	----	1	----	----	----	1	----	----	----	1	----	1	1	----	1	----	----	----	----	----	11
Missouri Pacific Railroad	2	----	1	1	1	----	1	2	2	----	1	3	2	2	1	1	----	----	1	1	1	----	3	1	2	1	----	1	----	----	1	32
Mobile & Ohio	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	1	----	----	----	----	3
Newburgh & South Shore	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
New York, Chicago & St. L.	----	----	----	1	1	----	----	----	----	----	----	----	2	----	----	----	----	----	1	----	2	----	----	----	----	----	----	----	----	----	----	7
Nashville, Chattanooga & St. Louis	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
New York, Ontario & West'n	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
New York Central Lines	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Boston & Albany	----	----	----	----	----	1	----	----	1	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	3
Big Four	----	----	1	----	----	----	----	1	1	----	1	----	----	1	2	1	----	----	----	----	----	1	----	----	1	----	----	1	1	----	----	12
Michigan Central	1	----	----	----	1	----	----	----	1	1	1	1	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	7
New York Central Railroad	----	2	1	1	3	2	----	3	4	1	1	1	1	1	3	----	1	1	----	2	2	2	2	3	4	2	2	1	----	1	----	47
Peoria & Eastern	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	2
Pittsburgh & Lake Erie	1	----	----	----	----	1	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	3
New York, New Haven & Hartford	----	1	----	1	----	2	----	----	1	----	1	----	----	2	1	----	----	1	----	3	----	----	1	1	1	----	1	1	----	----	1	19
Norfolk and Western	----	----	----	1	1	1	----	1	1	----	1	----	----	1	1	----	----	1	----	----	----	2	2	----	1	----	----	2	----	----	----	16
Norfolk Southern	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	1	----	----	----	----	----	----	----	2
Northern Pacific	----	----	1	1	1	----	----	1	2	----	1	----	1	----	----	2	2	----	----	----	1	----	1	----	1	----	----	----	----	----	----	15
Oregon Short Line	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	1
Piedmont & Northern	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	1
Pennsylvania	----	2	2	3	2	----	----	2	1	2	2	1	3	2	1	1	1	1	1	1	2	----	1	4	2	1	2	----	1	1	----	42
Pere Marquette	1	----	1	----	1	----	----	----	1	----	1	----	1	----	1	----	----	----	----	----	1	----	----	----	1	----	----	----	----	----	----	9
Pittsburgh, Chartiers & Youghiogheny	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Reading	----	1	----	1	----	----	----	----	1	----	----	----	1	----	1	----	----	1	----	1	----	----	----	----	1	----	----	----	----	----	----	8
Richmond, Fredericksburg & Potomac	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	1	----	----	----	1	----	----	----	----	----	----	----	3
Rutland	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	2
St. Louis Southwestern	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	2
Seaboard Air Line	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	1	----	----	----	1	----	----	----	----	----	----	----	----	3
Southern	1	----	----	1	----	----	----	----	----	1	----	1	1	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	6
Soo Line	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	1	----	----	----	----	----	----	2
Southern Pacific (Northwestern Pacific)	1	1	----	2	1	----	1	----	3	1	----	----	----	1	----	----	2	1	----	1	1	----	----	----	1	----	----	----	----	----	1	18
Temiskaming & No. Ontario	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	2
Tennessee Coal, Iron & R. R. Co.	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Term. R. R. Assn. of St. Louis	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Texas & Pacific	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Texas Pacific—Missouri Pacific Terminal	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	1	----	----	----	----	----	----	----	----	----	2
Third Avenue Railway	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Toledo Terminal	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	2
Toronto Terminals	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	1	----	1	----	----	----	----	----	----	----	3
Union Pacific	----	----	----	1	----	----	----	----	----	1	----	----	1	----	1	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	5
Union Railway (Memphis)	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Wabash	----	----	1	----	----	----	1	1	2	----	1	1	1	2	1	1	----	----	----	----	2	----	----	----	1	----	----	----	1	----	----	16
Wheeling & Lake Erie	----	1	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Western Maryland	----	----	----	----	----	----	----	----	1	----	----	----	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Non-Railroad	5	4	2	2	14	4	5	11	6	3	2	1	1	14	13	10	14	----	3	8	2	3	3	1	2	11	----	2	----	----	1	147
Foreign	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	1	----	----	----	----	----	----	----	----	2
Total	38	23	25	44	60	22	22	38	54	24	39	25	40	43	43	23	34	14	22	40	33	27	33	32	39	21	16	15	9	6	9	913

COMMITTEE-WORK

The reports of the several committees may be classified into three groups—(1) reports dealing principally with revisions of matter heretofore adopted; (2) reports containing new material offered for approval; and (3) reports containing useful information, and this category might also include bibliographies.

Under the first heading, most of the standing committees have devoted the major portion of their activities during the year to a critical examination of their material in the current Manual, with the view to perfecting such matter by eliminating obsolete subjects, condensing the remainder, and generally overhauling the chapter for which they are sponsors. This has been a laborious undertaking, but a review of the reports will show that the work has been well and conscientiously done.

Under the second grouping, a substantial amount of new matter has advanced sufficiently to warrant the respective committees to submit it for approval at the ensuing convention.

The third class of reports consists of material not suitable for the Manual, but which is of the character of useful and practical information and which is available to the man in search of data relating to a particular problem.

The bibliographies included in certain reports are helpful to the student in directing him to other sources of information pertaining to specific subjects.

The principal matters reported on by the respective committees are enumerated in the following summary:

Roadway .... Bulletin 381

Physical Properties of Earth Materials
Natural Waterways
Service Life of Culverts
Specifications for Cast Iron Culvert Pipe
Specifications for Corrugated Metal Pipe
Specifications for the Formation of the Roadway
Roadway Drainage
Tunnels
Bibliography of Articles on Tunneling Methods and Tunnels
Signs

Ballast .... Bulletin 384

Specifications for Stone Ballast
Cooperative Tests on the Cementing Value of Rock for Railroad Ballast
Report on Specification Test Limits for Stone Ballast
Specification for Prepared Blast Furnace Slag Ballast

Ties .... Bulletin 383

Extent of Adherence to Specifications
Specifications for Pre-Adzing and Pre-Boring Cross-Ties
Specifications for Machining Cross-Ties

Rail .... Bulletin 383

Details of Mill Practice
Rail Failure Statistics for 1934
Transverse Fissure Statistics for 1934
Rail Lengths in Excess of 39 Feet
Cause of the Corrugation of Rails
Joint Bars for 90-lb. and 100-lb. RE Rail Sections

Track .... Bulletin 383

Continuous Welding of Rail
Plans and Specifications for Track Tools
Plans for Switches, Frogs, Crossings, Slip Switches
Tie Plates for RE Rail Sections

Buildings ....Bulletin 382

- Specifications for Cement Grouted Macadam Pavements, Floors and Platforms
- Determination of the Destructible Value of Structures Which can be Collected in Case of Fire
- Application of Stainless and Rust-Resisting Metals to Building Construction

Wood Bridges and Trestles ....Bulletin 384

- Simplification of Grading Rules and Classification of Timber for Railway Uses
- Overhead Wood or Combination Wood and Metal Highway Bridges
- Design of Wood Trestles for Heavy Loadings
- Bearing Power of Wood Piles
- Recommended Relationships Between the Energy of Hammer and the Weight or Mass of Pile for Proper Pile Driving
- Design of and Specifications for Washers, Separators, Cap-Stringer Straps and Other Wood Bridge and Trestle Fastenings

Masonry ....Bulletin 384

- Specifications and Principles of Design of Plain and Reinforced Concrete
- Design in Reinforced Concrete of Rigid-Frame Bridges Without Skew
- Progress in the Science and Art of Concrete Manufacture
- General Specifications for Sub-Structures of Railway Structures
- Methods and Practices of Lining and Relining Tunnels
- Design of Expansion Joints Involving Masonry Structures

Highways ....Bulletin 384

- Comparative Merits of Various Types of Grade Crossing Protection
- Difference in Costs of Highways of Various Types Due to Different Weights and Lengths of Trucks
- Automatic Pumping Stations for Use in Connection With Elimination of Grade Crossings

Signals and Interlocking ....Bulletin 381

- Developments in Railway Signaling
- Principal Current Activities of the Signal Section

Records and Accounts ....Bulletin 384

- Office and Drafting Room Practices
- Recommended Practice to be Followed with Respect to Maintenance of Way Accounts and Statistical Requirements
- Construction Reports and Records
- Methods and Forms for Gathering Data for Keeping Up to Date the Property Records of Railways with Respect to Valuation, Accounting, Depreciation and Other Requirements
- Changes or Revisions in ICC Classification of Accounts

Rules and Organization ....Bulletin 384

- Rules for Fire Protection

Water Service, Fire Protection and Sanitation ....Bulletin 383

- Cause of and Remedy for Pitting and Corrosion of Locomotive Boiler Tubes and Sheets
- Types of Lime and Soda Ash Equipment in Treated Water
- Water Conditions Affecting the Extension of Locomotive Washout Periods

Yards and Terminals ....Bulletin 383

- Coal Transfer Terminals
- Scales Used in Railway Service
  - Specifications for the Manufacture and Installation of Four-Section Knife-Edge Railway Track Scales
  - Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-Contained and Portable Scales for Railway Service
- Bibliography on Subjects Pertaining to Yards and Terminals Appearing in Current Periodicals

Iron and Steel Structures ....Bulletins 382–384

- Rules for Rating Existing Iron and Steel Bridges

Economics of Railway Location ....Bulletin 381

- Operating Data Essential to Establish Units for Making Line and Grade Revisions to Meet Operating Requirements
- Effect of Speeds in Excess of 75 Miles per Hour on the Economics of Railway Location

Wood Preservation ....Bulletin 383

- Service Test Records for Treated Ties
- Piling Used for Marine Construction
- Destruction by Termites and Possible Ways of Prevention
- Effect of Preservative in Treated Ties in Track Due to Blowing Off Locomotives on Line of Road

Electricity .... Bulletin 383
- Summary of Reports of Electrical Section

Uniform General Contract Forms .... Bulletin 381
- Form of Agreement for Cab Stand Privileges
- Form of Agreement for Store-Door Delivery

Economics of Railway Operation .... Bulletin 383
- Method for the Determination of Proper Allowance for Maintenance of Way Expense Due to Increased Use and Increased Investment
- Cost of Stopping and Starting Trains
- Effect of Volume of Traffic on Railway Operating Expenses
- Operation with Reduced Number of Main Tracks

Economics of Railway Labor .... Bulletin 382
- Analysis of Operations of Railways that have Made Marked Progress in Reduction of Labor Required in Maintenance of Way Work
- Economics of Methods of Weed Killing
- Gang Organization and Methods of Performing the More Common Tasks of Maintenance of Way Work
- Out-of-Face Renewal of Track in View of the Increasing Life of Basic Units of Track Construction
- Economics in Track Labor to be Effected in the Maintenance of Joints by Welding and the Use of Reformed Bars
- Effects of Recent Developments in Maintenance of Way Practices on Gang Organization
- Comparative Costs of Maintaining Track on Various Kinds of Ballast

Shops and Locomotive Terminals .... Bulletin 381
- Oil Houses
- Paint Stores
- Adaptation of Enginehouses, Shops and Engine Terminal Layouts for Handling Oil-Electric Locomotives and Rail Cars
- Power Plants
- Car Wheel Shops

Waterways and Harbors .... Bulletin 382
- Types of Construction for Levees, Dikes and Mattresses for Use Under Varying Service Conditions
- Economic Principles Involved in Clearances Over Inland Navigable Waterways
- Clearances for Structures Over Navigable Waterways
- Cost to Railways for Construction, Maintenance and Operation of Bridges Over Navigable Waterways

Standardization .... Bulletin 382
- American Standards Association
- Canadian Engineering Standards Association
- Tabulation of Specifications and Recommended Practices as Contained in the Manual and Supplemental Bulletins
- Standards Approved by American Standards Association
- American Standards Association Technical Projects on Which the Association of American Railroads is Now Cooperating

Maintenance of Way Work Equipment .... Bulletin 381
- Standardization of Parts and Accessories for Railway Maintenance Motor Cars
- Track Grinders
- Selection and Training of Maintainers and Operators of Work Equipment
- Concrete Mixing and Concrete Handling Machinery
- Manual of Instructions for the Care and Operation of Work Equipment

Clearances .... Bulletin 382
- General and Detailed Clearance Diagrams

Waterproofing of Railway Structures .... Bulletin 384
- Principles Governing Waterproofing or Dampproofing
- Waterproofing and Dampproofing as Applied to Existing Railway Structures
- Specifications for Bituminous Emulsions

Stresses in Railroad Track .... Bulletin 381
- Progress Report

Live Load and Impact .... **Bulletin 382**
- **Live Load—Impact**

PUBLICATIONS

The mediums employed by the Association to disseminate the information and data developed pertaining to subjects coming within its province are the Monthly Bulletin, the annual volume of the Proceedings, and the Manual of Recommended Practice.

The Bulletin is issued ten times per year, and keeps the members currently informed of progress in committee-work; the publication of special papers or monographs contributed by members and others; the reports of committees issued in advance of the annual meetings, to afford members an opportunity to give such reports due consideration before taking action thereon.

The annual volume of the Proceedings represents the permanent official record of the Association's current activities. It contains, first, the result of the committees' work; second, the verbal and written discussions thereon, and, third, the action taken at the annual meeting on the recommendations submitted.

The Proceedings contain a vast amount of timely and useful information on subjects relating to railway engineering and maintenance problems, and on some phases of operation.

As an instance of the wide dissemination of this knowledge throughout the world, the following note is pertinent. H. D. Bindley, on the staff of the Chief Engineer's office of the Sudan Railways of Africa, a member of the AREA, contributed an interesting monograph to the Journal of the Institution of Civil Engineers of Great Britain in the November 1935 issue, entitled "Sudan Railways, 1925–1935," in which reference is made to the report of the Committee on Roadway, Proceedings for 1934, on the subject of sand dunes, from which the following is quoted: "Attention is being given to the elimination or anchoring of sand dunes, which threaten to cover the railway track over one section of the line, and drift sand also causes considerable blocking up of bridge and culvert openings on other sections. A very full summary of the experience of many railways was published by the American Railway Engineering Association in their Vol. 35 of the Proceedings, and some of the experiments recorded therein are being adapted to local conditions and tried out. It is estimated that the annual cost of keeping the one length of 35 kilometers of track free from sand for the safe passage of trains amounts to approximately 700 pounds sterling per annum."

The "Manual of Recommended Practice" represents the net results of the Association's accomplishments since its formation. It contains the specifications, plans, designs, general principles of practice, and conclusions relating to railway engineering in all its phases. It is proposed to issue a revised Manual during the current year.

Monographs.—The Bulletin contained three interesting monographs during the past year, as follows:

"Progress Report of the Joint Investigation of Fissures in Railroad Rails," by H. F. Moore, Research Professor of Engineering Materials, in Charge of Investigation, University of Illinois. This investigation, sponsored jointly by railways and rail manufacturers, is now in its fifth year. Its purpose is to ascertain the cause of transverse fissures in steel rails and to devise a remedy therefor.

"Landslides, Subsidences and Rock-Falls," by Dr. George Edgar Ladd, Consulting Engineer-Geologist, U.S. Bureau of Public Roads, a member of the AREA and of the Committee on Roadway. Dr. Ladd is an acknowledged authority on this subject, and has made available a vast amount of valuable data in his paper.

"Impact in Steel Railway Bridges of Simple Span, as Designed from Tests Made on the Cleveland, Cincinnati, Chicago and St. Louis Railway," by J. B. Hunley, Engineer of Bridges and Structures.

This monograph is an outstanding and exceedingly valuable contribution to the knowledge of the subject of impact on railway bridges. It makes available in convenient form the results of comprehensive tests and studies extending over a four-year period. The paper should be of special importance, not only to Bridge Engineers, but should also be read by railway Mechanical Engineers, as well as by Engineers of locomotive building companies. It was published in Bulletin 380 for October 1935.

"Blue Book."—In addition to the regular publications, the so-called "Blue Book" was issued during the year. The contents consist of Specifications for the Design and Construction of Steel Railway Bridges and for Concrete Railway Structures. The pamphlet is intended primarily for use by railways, State Highway Commissions, and contractors for all work on PWA projects covered by AREA specifications. Authority for issuing this publication under the auspices of the Association of American Railroads was given in the fall of 1935.

Advance Publication of Discussions as Annual Meetings.—The valuable suggestion made by a member a year ago, that the verbal discussions at annual meetings be abstracted and issued in preliminary form as soon as practicable after adjournment, was favorably acted on by the Board of Direction. The June 1935 Bulletin contained abstracts of discussions on Iron and Steel Structures, Wood Bridges and Trestles, Water Service, Track, and Definition of Terms pertaining to Public Improvement Projects. The practice will be continued.

MISCELLANEOUS

Special Committee on Live Load and Impact.—The Board of Direction, at a meeting held June 7, 1935, authorized the appointment of a special committee of nine, with equal representation from the Committees on Masonry, Wood Bridges and Trestles and Iron and Steel Structures, for the purpose of giving study to the subject of live load and impact.

Change in Title of Committee VII.—On the recommendation of Committee VII, the title of that group has been changed to "*Wood* Bridges and Trestles", the change consisting of the substitution of the word "Wood" for "Wooden."

Use of Phrase "and/or" in Legal Documents Declared Illegal in Illinois.—Justice O'Connor, of the Illinois Appellate Court, has ruled that the phrase "and/or," employed in some legal documents, such as agreement forms, contracts, and also in specifications, is illegal, as being indefinite and open to disputes and consequent litigation.

This ruling has been brought to the attention of the Committee on Uniform General Contract Forms, as the phrase appears in a number of agreement forms formulated by the Committee. The Committee has given the matter prompt consideration and decided to recommend the elimination of all "and/or" expressions in the Committee's adopted forms, and will offer for approval at the convention the substitution of either "and" or the word "or," as the case may be, in three agreement forms.

Railway Engineering and Operating Questions.—An inquiry from a prominent Railway Executive, covering seven questions, was referred to the Association for reply, in October of 1935. As an answer was desired within a certain specified time, prompt action was necessary. The cooperation of men specially qualified by experience and training was enlisted, and based on their responses, plus data derived from the files of the Association, a reply was returned within the allotted time. The seven questions asked are quoted below, as a matter of interest:

1. The average annual cost of maintaining roadway and track now as compared to 1920, or thereabouts.
2. The extent to which improvements and inventions, such as treating cross-ties, have resulted in economy in maintenance.
3. The difference in construction and maintenance cost of roadway and structures designed for speeds of about 50 miles an hour as compared with speeds of 75 to 80 miles per hour.
4. The actual advantage, if any, in streamlining and, particularly, the ability on that account to increase speeds and reduce fuel charges.
5. Have there been any outstanding developments in keeping roadway drained through tiling, improved culverts or otherwise?
6. To what extent do modern steam locomotives, in speed, drawbar pull and fuel consumption compare with the best locomotives of 15 or 20 years ago?
7. Is there any reliable data available as to comparative operating efficiency of steam locomotives with electrical locomotives, giving no consideration to capital costs?

Cooperation with Other Technical Organizations.—Contact has been maintained with other technical organizations on subjects of mutual concern. The following list will indicate the wide range and diversity of interests involved in such collaboration:

Association of American Railroads
American Society of Civil Engineers
American Society for Testing Materials
American Society of Mechanical Engineers
American Standards Association
American Transit Association
American Wood Preservers' Association
Central Committee on Lumber Standards
Chemical Warfare Service, U. S. Army
Edison Electric Institute
Forest Products Laboratory
Forged Tool Society
Joint Committee on Automatic Train Control
Joint Committee on Concrete and Reinforced Concrete
Joint Committee on Grade Crossing Protection
Joint Committee on Railway Sanitation
Manganese Track Society
National Bureau of Engineering Registration
National Scalemen's Association
Portland Cement Association
Rail Manufacturers' Technical Committee
Railway Fire Protection Association
University of Illinois, Engineering Experiment Station

Requests for Funds for Research.—During the past year, the Association of American Railroads was appealed to for funds for conducting Boiler Feed Water Studies, Impact on Steel Railway Bridges, and Structural Welding. Data in support of these projects were submitted, and later supplemented by additional arguments. These requests are being given due consideration by the proper authorities of the AAR, and it is hoped that favorable action will be taken in due course.

Acknowledgment.—The loyal, faithful and efficient services rendered by the office staff is gratefully acknowledged.

E. H. Fritch,

Secretary.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1935

Balance on hand January 1, 1935		$79,187.93
RECEIPTS		
Membership Account		
Entrance Fees	$ 560.00	
Dues	18,188.92	
Binding Proceedings	1,604.29	
Sales of Publications		
Proceedings	1,955.80	
Bulletins	1,672.89	
Manual	243.75	
Specifications	780.90	
Track Plans	322.00	
Advertising		
Publications	709.60	
Interest Account		
Investments	2,582.79	
Bank Balance	6.57	
Miscellaneous	53.57	
American Committee on Electrolysis	107.05	
A.A.R. Pension Refund	213.26	
Total	$29,001.39	
DISBURSEMENTS		
ORDINARY:		
Salaries	$ 8,714.00	
Proceedings	5,359.06	
Bulletins	5,596.00	
Track Plans	495.00	
Stationery and Printing	710.70	
Rents, Light, etc.	832.70	
Supplies	79.25	
Expressage	246.98	
Postage	468.32	
Exchange	85.45	
Committee Expenses	131.52	
Officers' Expenses	35.35	
Annual Meeting	1,001.77	
Refunds, dues, etc.	10.50	
Audit	200.00	
Pension (A. K. Shurtleff)	1,200.00	
A.A.R. Employees' Pension Fund	94.72	
Miscellaneous	49.80	
Total Ordinary Disbursements	$25,311.12	
Excess of Receipts over Ordinary Disbursements	3,690.27	
EXTRAORDINARY:		
*Manual Revision Work	4,799.49	
Excess of Total Disbursements over Receipts account Manual Revision Work		1,109.22
Balance on hand December 31, 1935		$78,078.71

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* Extraordinary expenditures include the Manual Revision Work, authorized by Board of Direction, March 14, 1935, and is properly chargeable to surplus.

REPORT OF THE TREASURER

March 1, 1936.

To the Members:

Balance on hand January 1, 1935		$79,187.93
Receipts during 1935	$29,001.39	
Paid out on Audited Vouchers, 1935	30,110.61	
Excess of Total Disbursements over Receipts		1,109.22

* Total Disbursements include Extraordinary Expenditure account Revision of Manual Work.

Balance on hand December 31, 1935		$78,078.71
Consisting of		
Bonds at cost	$72,310.64	
Cash in Northern Trust Company Bank	5,328.81	
Cash in Royal Bank of Canada	414.26	
Petty Cash	25.00	
	$78,078.71	

Respectfully submitted,

A. F. Blaess, *Treasurer.*

I have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1935, and find them to be in accordance with the foregoing Financial Statements.

Charles Campbell, *Auditor.*

GENERAL BALANCE SHEET

December 31, 1935

Assets	1935	1934
Due from Members	$ 2,472.97	$ 3,037.00
Due from Sales of Publications	117.95	212.65
Due from Advertising	10.00	25.00
Furniture and Fixtures	338.00	394.00
Gold Badges	37.50	37.50
Publications on hand (Estimated)	2,000.00	2,000.00
Extensometers	250.00	300.00
Investments (Cost)	72,310.64	71,777.52
Interest on Investments (Accrued)	438.42	398.85
Cash in Northern Trust Company Bank	5,328.81	7,083.38
Cash in Royal Bank of Canada	414.26	302.03
Petty Cash	25.00	25.00
Manual Revision Work	4,799.49	....
Total	$88,543.04	$85,592.93
Liabilities		
Member's Dues paid in advance	$ 4,464.50	$ 4,221.71
Surplus	84,078.54	81,371.22
Total	$88,543.04	$85,592.93

The President:—Gentlemen, you have heard the reports of the Secretary and of the Treasurer. What is your pleasure?

Mr. George W. Kittredge (Past-President):—It is such a pleasure and gratification in these days to see a budget that has been balanced that I take pleasure in offering the following resolution:

"Resolved, That the reports of the Secretary and of the Treasurer be approved."

The President:—Is the motion seconded?

Mr. C. W. Baldridge (Atchison, Topeka & Santa Fe):—I second the motion.

(The motion was put to vote and carried.)

The President:—It is unanimous. I shall take it as the sense of the convention that no further action is considered necessary. With reference to the deceased members included in the report of the Secretary, I will ask the convention to arise for a moment in silent tribute to these men.

(The convention arose and stood in silent tribute to the memories of the deceased members.)

The President:—The privileges of the floor are extended to visiting delegations, railroad officials, or other persons not members of this Association, and to Professors of colleges and similar institutions. They are invited to take part in discussion of the subjects in which they are interested.

In extending this customary invitation I desire, on behalf of the Board of Direction and the administrative officers of this Association, to make it a very special one to the younger members. May I say to them, do not be afraid to give expression to your views, because it frequently happens that valuable information may be presented as well as the thoughts thus expressed may perhaps suggest a new line of thought in the minds of others, and in turn, alter the channels of action which have heretofore prevailed. All reports presented during this convention originate with definitely assigned problems given to the standing or special committees by the Board of Direction. Our committees are required, after proper study and examination, to make definite reports upon these problems. The result of these examinations and the conclusions reached are shown in the printed reports which are now before this convention. Past experience has shown that the best results are obtained by confining discussion as closely as practicable to the definite problems which are being reported upon by the committees and for this reason I trust that the speakers will keep the subject as presented by the committee clearly before them and confine their remarks as closely as possible to the subject under discussion.

The Board of Direction is now excused.

The first report is from Committee XXVI—Standardization. It will be presented by Mr. E. M. Hastings, Chief Engineer, Richmond, Fredericksburg & Potomac Railroad, Chairman of the Committee.

(For Report, see pp. 205–217.)

The President:—The next Committee to report is that of the Committee on Roadway. Its Chairman, Mr. Geo. S. Fanning, Chief Engineer, Erie Railroad, will please present the report.

(For Report, see pp. 113–155.)

The President:—The next report is that of the Special Committee on Stresses in Railroad Track, of which Dr. A. N. Talbot, Professor-Emeritus, University of Illinois, is Chairman.

(For Report, see pp. 101–102)

The President:—The next report is that of the Committee on Yards and Terminals. Mr. M. J. J. Harrison, General Scale Inspector, Pennsylvania Railroad, is Chairman, and will present the report.

(For Report, see pp. 307–382.)

AFTERNOON SESSION

The President:—The first report this afternoon is that of Committee XIII—Water Service, Fire Protection and Sanitation. Mr. R. C. Bardwell, Superintendent Water Supply, Chesapeake & Ohio Railway, is Chairman, and will please present the report.

(For Report, see pp. 383–415.)

The President:—I desire at this time to obtain approval of the convention for a change in the regular program to allow Committee X—Signals and Interlocking to present its report immediately following the opening of the session tomorrow morning, and if there is no objection we will proceed on that basis.

Committee XVIII—Electricity will now come to the platform, Mr. J. V. B. Duer, Chairman. The report of the Committee will be presented by Mr. G. I. Wright, Vice-Chairman of the Committee, in the unavoidable absence of Mr. Duer. Incidentally, Mr. Wright is the newly-elected Chairman of the Electrical Section, Association of American Railroads.

(For Report, see pp. 557–558.)

The President:—Will Committee XXI—Economics of Railway Operation please come to the platform. In the absence of its Chairman, Mr. J. E. Teal, the report will be presented by its Vice-Chairman, Mr. M. F. Mannion.

(For Report, see pp. 535–556.)

The President:—Committee XXII—Economics of Railway Labor will please come to the platform. The report of this Committee will be presented by its Chairman, Mr. F. S. Schwinn, Assistant Chief Engineer, Missouri Pacific Lines.

(For Report, see pp. 235–264.)

The President:—I desire at this time to again call attention to the exhibit at the Coliseum of the National Railway Appliances Association. This display of devices is of special interest to Railway Engineers and others associated with engineering and maintenance of way. It should also be of great interest and educational value to all persons interested in the subject of transportation. It is hoped that members and guests will avail themselves of this opportunity to visit the Coliseum.

WEDNESDAY, MARCH 11, 1936

MORNING SESSION

The President:—The convention will please come to order.

The Committee on Signals and Interlocking will please come to the platform. As announced yesterday, the report of Committee X was postponed until this morning. Chairman C. H. Tillett, Signal Engineer, Canadian National Railways, will present the report.

(For Report, see pp. 65–68.)

The President:—Committee II—Ballast will please come to the platform. The report of the Committee will be presented by its Chairman, Mr. A. D. Kennedy, Assistant Engineer, Atchison, Topeka & Santa Fe Railway.

(For Report, see pp. 559–576.)

The President:—The report of Committee III—Ties, will be presented by its Chairman, Mr. John Foley, Forester of the Pennsylvania Railroad.

(For Report, see pp. 417–420.)

The President:—Will Committee IV—Rail please come to the platform. The report will be presented by its Chairman, Mr. Earl Stimson, Chief Engineer Maintenance, Baltimore & Ohio Railroad.

(For Report, see pp. 421–462.)

(First Vice-President A. R. Wilson in the chair.)

First Vice-President A. R. Wilson):—The report of Committee V—Track, will be presented by the Chairman, Mr. C. J. Geyer, Engineer Maintenance of Way, Chesapeake & Ohio Railway.

(For Report, see pp. 463–507.)

Vice-President A. R. Wilson:—I wish to announce that Mr. S. C. Johnson and associates will act as tellers to canvass the vote for officers for the ensuing year. The Secretary will turn over the ballots to this committee. The committee will report on the election at the session tomorrow afternoon.

The next Committee will please come to the platform, the Special Committee on Complete Roadway and Track Structure, Mr. John V. Neubert, Chairman, will present the report. Mr. Neubert is Chief Engineer Maintenance of Way, New York Central Lines.

(For Report, see page 69.)

(President Ford in the chair.)

The next report is that of Committee XVII—Wood Preservation. Mr. C. F. Ford, Supervisor Tie and Timber, Rock Island Lines, Chairman, will please present the report.

(For Report, see pp. 509–533.)

The President:—The next report is that of Committee XV—Iron and Steel Structures. Mr. G. A. Haggander, Bridge Engineer, Chicago, Burlington & Quincy Railroad, will please present the report.

(For Report, see pp. 265–271; 729–735.)

The President:—The Special Committee on Live Load and Impact will please come to the platform. Mr. O. F. Dalstrom, Bridge Engineer, Chicago & Northwestern Railway, Chairman, will present the report.

(For Report, see pp. 273–274.)

The President:—Sitting in the Convention is a very versatile man of unusual ability who has established an enviable reputation in the field of education and engineering, and whom the American Railway Engineering Association is glad to honor, Dr. Daniel Mead, President of the American Society of Civil Engineers. I shall ask Dr. Mead to please rise (Applause).

Near Dr. Mead is another well-known Engineer of national prominence and a member of this Association, Mr. Alonzo J. Hammond, Consulting Engineer of Chicago, and a Past-President of the American Society of Civil Engineers. I shall ask Mr. Hammond to please rise (Applause).

The President:—The Special Committee on Economics of Bridges and Trestles will please come to the platform. Mr. Arthur Ridgway, Chief Engineer, Denver & Rio Grande Western Railway, is Chairman, and will please present the report.

(For Report, see page 99.)

The President:—The next report is that of Committee VII—Wood Bridges and Trestles. The Chairman, Col. H. Austill, Bridge Engineer, Mobile & Ohio Railroad, will tell the convention what action is desired.

(For Report, see pp. 665–721.)

The President:—The Committee on Masonry will please come forward. Its Chairman, Mr. Meyer Hirschthal, Concrete Engineer, Delaware, Lackawanna & Western Railroad, will present the report to you.

(For Report, see pp. 631–654.)

The President:—The Special Committee on Waterproofing of Railway Structures will now come to the platform. The Chairman, Mr. J. A. Lahmer, Senior Assistant Engineer, Missouri Pacific Railroad, will please present the report.

(For Report, see pp. 655–664.)

THURSDAY, MARCH 12, 1936

MORNING SESSION

The President:—The first report this morning is that of Committee IX—Highways. In the absence of both the Chairman and the Vice-Chairman, the report will be presented to you by Mr. G. P. Palmer, Engineer Maintenance and Construction, Baltimore & Ohio Chicago Terminal Railroad.

(For Report, see pp. 577–592.)

The President:—The Committee on Waterways and Harbors will please come to the platform. The Acting Chairman, Mr. G. P. Palmer, Engineer Maintenance and Construction, Baltimore & Ohio Chicago Terminal Railroad, will present the report.

(For Report, see pp. 219–233.)

The President:—The Chair recognizes the President of the Western Railway Club, Mr. Lee Robinson, Assistant General Superintendent Motive Power, Illinois Central System. Will Mr. Robinson please rise?

The President:—The next report on the Docket is that of Committee XI—Records and Accounts. Its Chairman, Mr. C. C. Haire, Engineer Capital Expenditures, Illinois Central System, will please present the report.

(For Report, see pp. 593–630.)

The President:—Committee XX—Uniform General Contract Forms will please come to the platform. Its Chairman, Mr. F. L. Nicholson, Chief Engineer, Norfolk Southern Railway, will present the report.

(For Report, see pp. 81–98.)

The President:—The next report is that of Committee XXVII—Maintenance of Way Work Equipment. The Chairman, Mr. C. R. Knowles, Superintendent Water Service, Illinois Central System, will tell the convention what action is desired.

(For Report, see pp. 157–203.)

The President:—The Committee on Economics of Railway Location will please come to the platform.

While the Committee is assembling, I am sure the Convention will be interested in the following communication from Mr. J. J. Pelley, President of the Association of American Railroads:

> "Dear Mr. Ford:
>
> "Thanks for your letter of March 4 with its very kind invitation to me to attend the luncheon of the American Railway Engineering Association, to be held in connection with your Annual Convention at the Palmer House, Chicago, Wednesday, March 11.
>
> "I should like very much to be able to attend. It is a matter of regret, however, that prior and definite appointments in Washington on that date will prevent my being with you. Were it not for this, it would be a pleasure to be on hand."

Communications of similar tenor have been received from General E. M. Markham, Chief of Engineers, U.S.A., and Mr. Thomas H. MacDonald, Chief of the Bureau of Public Roads. Both these men are able Engineers, with distinguished records for public service, and it is a matter of regret that they are not able to be with us today as they intended.

The report of Committee XVI—Economics of Railway Location will now be presented by its Chairman, Mr. F. R. Layng, Chief Engineer, Bessemer & Lake Erie Railroad.

(For Report, see pp. 103–111.)

The President:—Before I go further I want to call the attention of the convention to the need for increasing the membership. The Board of Direction and the administrative officers of your Association believe it is very much to the interest of all concerned that the membership be substantially increased.

I should like to urge upon you if you will, during the year, to aid your Association and officers by contacting Engineers generally. We want to increase our membership materially, in the interest of the Association, in the interest of you, and in the interest of the work we are doing.

AFTERNOON SESSION

The President:—The first report this afternoon is that of the Special Committee on Clearances. The Chairman, Mr. A. R. Wilson, Engineer Bridges and Buildings, Pennsylvania Railroad, will please present the report.

(For Report, see pp. 291–305.)

The President:—The Chair desires to recognize at this time the President of the Western Society of Engineers. Mr. Frank Fowle. Mr. Fowle will please rise (Applause).

The President:—The next Committee on the Docket is that of Committee VI—Buildings. The Chairman is absent, and I will ask the Vice-Chairman, Mr. O. G. Wilbur, Assistant Engineer, Baltimore & Ohio Railroad, to present the report.

(For Report, see pp. 275–290.)

The President:—The Committee on Shops and Locomotive Terminals will please come to the platform. The report will be presented by Mr. J. M. Metcalf, Assistant Chief Engineer, Missouri-Kansas-Texas Lines.

(For Report, see pp. 71–79.)

The President:—The next and last Committee to report is that of Committee XII—Rules and Organization. The Committee's report will be presented by the Chairman, Mr. E. H. Barnhart, Assistant Division Engineer, Baltimore & Ohio Railroad.

(For Report, see pp. 723–728.)

The President:—Gentlemen, this completes the consideration of Committee reports. The Board of Direction and your administrative officers wish me to thank each one of these Committees and, through them, their members for the excellent work they have done this year. I have noted particularly in the presentation of the reports the thorough manner in which they have prepared their notes and it is indicative of the efficiency with which the work has been done.

It is with pleasure that I am able to announce that the total registration for 1936 slightly exceeds the registration of 1935. I know, of course, that is not very much of an excess but it is exceeded anyhow. The total last year was 907. Thanks to three of our good friends who sensed the situation, the total registration for this year is 910.

Our next order of business is "New Business." Has anyone anything to offer at this time

Past-President John E. Armstrong:—Those in attendance at this convention will no doubt have noticed the attractive signs displayed in this meeting room, being an enlargement of the insignia of the Association.

The Association is indebted to the Railway Age for its cooperation in the making of these decorative signs. I suggest that these remarks be made a part of the permanent record of this meeting.

The President:—Is there anything further?

Mr. John V. Neubert (New York Central):—Mr. President, in behalf of the Association and the group that gathered at luncheon yesterday, I offer a vote of thanks, and ask that it be so recorded in the Proceedings, for the splendid, elaborate and complete address made by Mr. Ralph Budd, President of the Burlington and Member of our Board of Direction of this Association. I so move.

Past-President John E. Armstrong:—I second the motion.

(The motion was put to vote and carried unanimously.)

Mr. J. C. Irwin (Boston & Albany):—Mr. Ford, you are about to be promoted once more, this time to the honorable status of Past-President of this Association, in which you will serve five years more as a member of the Board of Direction. Having worked very closely with you during your administration, I feel sure that no President has ever done more to make it known to all that the American Railway Engineering Association is the greatest railway organization in the world.

I have the honor, sir, to represent the Association in presenting to you this plaque in recognition of the time, energy and earnestness which you have devoted to its service.

The plaque carries the insignia of the Rock Island, Mr. Ford's road, and the inscription reads:

> "The American Railway Engineering Association records its grateful appreciation to Robert H. Ford, President, 1935–1936, for his untiring efforts to increase the effectiveness of the Association as an instrumentality through which talents of Railway Engineers may prove of maximum utility in advancing the economic value of rail transportation."

Mr. Ford, I congratulate you and thank you on behalf of the Association (Applause).

The President:—Thank you (Applause).

If there is no further business, I will ask the Secretary to announce the result of the election of officers. As their names are announced I will ask those named to please rise. No remarks are necessary.

The Secretary:—The report of the tellers is as follows:

"To the Members: We, the Committee of Tellers, find the results of the vote to be as follows:

For President: A. R. Wilson (Applause).
J. C. Irwin automatically becomes the First Vice-President (Applause).
For Second Vice-President: F. E. Morrow (Applause).
For Secretary: E. H. Fritch (Applause).
For Treasurer: A. F. Blaess (Applause).
For Directors (three to be elected):
H. R. Clarke (Applause).
F. L. C. Bond (Applause).
W. M. Post (Applause).

Five members of the Nominating Committee:
Richard Brooke
G. P. Palmer
B. R. Leffler
P. M. Gault
F. R. Judd (Applause).

The President:—Gentlemen, I want to offer my congratulations to the elected officers. If there is no further business, I will ask two of the members of Committee XV to escort your newly elected President up here where you can all see him.

(The convention arose and applauded).

The President:—Mr. Wilson, no higher professional honor can ever come to you or to any Railway Engineer than their elevation to the Presidency of the American Railway

Engineering Association. You and I have worked together for a long time. I know you to be an able and efficient Engineer who is a credit to our profession, and with you the affairs of this Association are left in splendid hands. Again I congratulate you as well as the Association on your selection (Applause).

(President-Elect A. R. Wilson assumed the chair.)

The President:—Mr. Ford and Members of the Association: The American Railway Engineering Association stands out in the front rank of engineering organizations. Its publications and recommended practices are recognized and quoted the world over. To be its President is to receive one of the highest honors in the engineering profession. The course of this Association was wisely charted by its founder members and through the able leadership and support of its members has weathered many storms. When elected Vice-President two years ago I realized then that with the fleeting of time this day would soon be here. Today it is a reality.

Mr. Ford, in accepting this gavel I know full well what it means, but with the continued support of the officers and the membership we can carry on. Knowing this Association as I do, full support will be forthcoming, and with it I pledge the best I have to record another successful milestone in the career of this Association. Thank you (Applause).

Is there any further business to come before the Association? If not, I will declare the Thirty-seventh Annual Meeting of the Association adjourned.

The Board of Direction will meet in Room 6 in about 30 minutes.

(The meeting adjourned at three-thirty o'clock.)

E. H. Fritch

Secretary

NEW OPPORTUNITIES OF THE RAILWAYS

By Ralph Budd
President, Chicago, Burlington & Quincy Railroad

Address before the American Railway Engineering Association at Chicago, March 11, 1936

The railroad problem would seem to be worn threadbare by the excessive amount of talking that has been directed at it and it is doubtful if any more talk, at least along conventional lines, will help toward a solution. I would not wilfully prolong a fruitless discussion, and in saying so am reminded of an incident at the end of a long day of apparently barren efforts to agree upon matters of policy. One who already had spoken a good deal arose and said, "I do not want to make another speech," whereupon another retorted with a show of great feeling, "Then for God's sake don't do it."

In defense of speaking now, may I observe that most of the talk about the railroad problem has dealt with the regulatory, taxation, financial and kindred phases of the subject, which may be called the public interest group. Not very much, or at least not a very large percentage, of the talking has dealt with problems of operation. The most of the discussion has been prompted by concern about the question "Why are the railways in such serious distress?", or more recently, "Why are the railways as an industry lagging behind the others in recovery?" This unfortunate state of affairs cannot be denied, but no single cause can be assigned. There are many collateral reasons for nearly 75,000 miles, or thirty per cent, of our railway mileage being in bankruptcy, or otherwise undergoing reorganization, and there are many varying opinions about the relative importance of these reasons.

It is said that overcapitalization is responsible for the railway's difficulties; that reduction of fixed charges, through scaling down of debts and lowering of interest rates, is all that is needed.

Some say rates are too high and should be lowered, others that rates must be raised to meet increased costs of labor and materials.

There are those who think everything will be all right when business generally is prosperous again. They point out that two years of serious underproduction on the farms, especially in the Middle West, have accentuated the effect of the depression.

Some people blame unregulated competitors, and think higher taxes for use of highways and stricter regulation of highway users would solve the railway problem.

Others believe that the railway labor union leaders, by now insisting upon the highest wages of the boom years, are chiefly responsible for the present plight of the roads.

Then there are the advocates of public ownership, who think the government could run the railways better than private companies.

It is easy to understand how a student, concentrating on some one or more of the many difficulties, may come to feel that the particular handicaps he sees are so great that removing them would bring success. Indeed it is generally conceded that the things I have enumerated are, together, responsible for a large part of the railways' predicament, and something is being done about them, or at least about some of them.

For example: Debts are being scaled down and interest rates are being lowered; the consequent strengthening of credit of the railways affected is important.

Rate reductions and rate increases both have been applied; the former to hold traffic or retrieve it from the highways and the latter to produce needed revenue from existing traffic, and that it was believed would continue to move by railway.

Business has improved and promises to continue to improve at least for some time in the future; the effect is like blood transfusion upon an anaemic patient.

There is promise of a return to normal farm production and that would help, especially the granger roads.

Regulation of highway carriers has made a beginning; it promises to bring relief from some very unfair practices, but necessarily its benefits will be in the future.

Railway labor leaders, however, have continued to hold to the view that they should not give up privileges or accept lower wages, in order that railway operating costs may be reduced, and railway rates adjusted to meet highway and waterway competition. On the contrary, according to my information, their position has been, and is, that further and special consideration should be accorded union railway employees, and that economies should not be made if they would result in laying off such employees.

What shall we say about government ownership? A bill is before the Congress providing for taking the roads over. It seems safe to say that there is no substantial support for this movement among those who would have to pay the bills, that is, among taxpayers and shippers.

Some of the subjects I have mentioned are quite controversial. Some of them are also quite indeterminable, and always will be debated. They are moreover, every one of them, questions of great importance and deserve the attention they have received and will continue to receive.

We are concerned here today, however, with another type of railroad problem and I think happily so. It is the building and maintaining of a better property over which to run trains, and handle traffic at terminals and other stations. Whatever the relative state of railroad prosperity, be it favorable or unfavorable; whatever the form of management, whether private or governmental; whatever the level of rates or of wages; whatever the policy of regulation or finance, the very foundation of railway service and success is the permanent way. And everything that makes the physical plant more perfect or improves the system of maintaining it, promotes the welfare of the railways and improves their position compared with what it would be otherwise, and, may I add, promotes the welfare of the employees as well.

The cost of maintaining permanent way and structures of Class I roads has averaged about $610,000,000 a year over a ten-year period, or about 17.4 per cent of total operating expenses, and 12.9 per cent of total revenues. That the average maintenance cost is far from the amount now being spent and far from what was spent in prosperous times, is evident from the fact that the figure was as high as $868,000,000 in 1927, and as low as $322,000,000 only six years later. It is surprising how closely the expenditure for maintenance of way and structures followed, downward, the amount of business done and the gross revenues, but it dipped lower than either of these in percentage of the 1927 figures. Several factors combined to make possible the very drastic reduction in maintenance during the depression. Unquestionably, the properties had been built up to a very high standard during the time when earnings were sufficient; then when traffic declined, the wear and tear was much less; there was also a moderate decline in the cost of materials and, for a time, in wages; again, more modern methods and better tools were employed, and the fact that working gangs were smaller, and supervision better, resulted in more effective application of labor; and with all of these there was, of course, a substantial amount of deferred maintenance.

It may sound overly optimistic to say that in this adversity of reduced maintenance expenditures, there may be the seeds of opportunity for the Railway Maintenance Engineers. But I believe that these latent opportunities do exist. How to take advantage of them may become the special objective of the American Railway Engineering Association.

In the first place, while it is confusing to the layman, all of us understand that maintenance of roadway and structures can be deferred for a considerable time without in any way impairing the usability of the railway. That is because of the relatively long life of many of the component parts, such as rail, ties and ballast. The many different parts are wearing out, one at a time and what happens when less than normal work is done on track and structures, is that some of the accumulated service life is used up. The question of safety is in nowise involved, but it does mean that after a period of such small expenditures for maintenance as we have experienced since 1929, there must come a period of much larger outlay. Of course, certain of the items are non-recurring, and a part of the deficiency, therefore, will not have to be made up. It is safe to say, however, that several hundred millions of dollars will be put back into roadway and structures during the next few years, and therein lies our opportunity. Periods of relative quiescence in manufacturing always result in rapid advancement in design and technique, and that has been the case with railway maintenance standards and specifications, as well as with tools and equipment, since 1929.

The National Railway Appliances Exhibit now at the Coliseum is an impressive demonstration of the progress that has been made during that period. The expenditures that will be made now and in the future will go much farther because of these improvements and inventions, the better designs of rail and other rolled sections, and finer quality of material used in track, bridges and buildings, than the same expenditures would have gone a few years ago. I consider the new rail sections to be of better design than we have had before, although I am aware that some slight modifications are being made. The same may be said of rail joints and tie plates. Heat treating of bolts and angle bars has proved highly successful, and now the "controlled cooled" and "normalized" processes promise something every railway official in any way responsible for track will appreciate, that is, rail more free from tendency to fissures. Of course, one cannot think of our new opportunities without thinking of the accomplishments of the metallurgists. They have revolutionized some technics, more particularly as applied to equipment manufacture thus far, but results in that field promise much for the future of maintenance of way and structures.

Only recently an officer of a manufacturing company made an address, in which he said that railway men have been laggard in the use of scientific research, and recommended that they organize highly trained and competent staffs in technical bureaus. Too often proponents of extensive railway research have attempted to show, or have assumed, an exact parallelism between what might be done by the railroads and what has been done by others, such as communications, automotive, steel industry, chemistry, etc. Enthusiasm about applying to unfamiliar fields the ideas that have brought phenomenal success in his own field can be readily understood, but enthusiasm is not always synonymous with understanding. Railways present a research problem quite different from some of the highly centralized industries whose development and progress has been based almost wholly on research work. I am strongly in favor of railways having every benefit from scientific knowledge. They have not been without such benefits, however, and I insist that railway men have shown both ingenuity and inventive capacity. And they have progressed splendidly in the field of applied sciences. In the language of the day, "Let us look at the record." To mention only two outstanding achievements, there are the Investigation of Stresses in Railroad Track, and the Investigation of the Transverse Fissure problem, the latter a joint undertaking by the railways and the manufacturers. For many years the custom has been for improvements in track and structures, tools and equipment, to be originated by men on the railroads, often in the maintenance of way department, or in the mechanical drafting room, and then for their inventions to be taken over by manufacturers. I believe it is fair to say that most of the patents under which railway supply people are manufacturing and selling to railroads, originated in railroad sources; certainly a great many of them so originated. It is very misleading to say that the Railway Engineers and others have not been diligent and progressive in the perfecting of existing railway plant. I believe the railway supply companies will agree that there are many advantages in the plan of having the railways purchase their supplies and equipment, rather than do the manufacturing in railroad shops. I seem to remember hearing that subject spoken of by several able representatives of railway appliances and equipment companies.

We do, however, need a highly organized research department to take advantage of developments that are now proceeding at an accelerated pace. The motif of this decade is speed, and our work must be keyed to a new tempo. The speed of freight trains is 50 per cent faster than it was ten years ago and the same is true of many passenger trains. There is nothing to indicate that axleloads are going to increase much, if any, but impact may be greater at the higher speeds that seem to be coming so irresistibly. I say impact *may* increase rather than it *will* increase because we do not know how much may be done by locomotive builders to lighten the weight of rods, pins, and other balanced and reciprocating parts. With lighter equipment there would be less ton-miles over the rails. That would make a difference in the wear and tear on track, as we have observed less ton miles have done during the depression. The possibilities of lighter weight equipment are intriguing. In 1934 approximately 400 billion ton-miles were made, in handling freight and passenger cars, exclusive of the loads they carried. If, as is quite possible, these cars should be reduced one-fourth in weight, it would require 100 billion less ton miles to handle the business. At one mill per ton-mile that is 100 million dollars a year.

We were speaking about research. My idea is that this should be amply financed by the Association of American Railroads and in charge of a competent Director. It should be organized on a permanent basis and I believe this Association should control the carrying out of the projects. In addition to office and laboratory work there are necessary activities in the field also, but the field work and the laboratory work must be tied together very closely. The railways can provide the service tests. They will be the proving grounds and also sources for new ideas in the future as they have been in the past. It is just as truly research for a foreman or roadmaster to observe and study the behavior of track in certain circumstances and report his findings, as it is for investigations to be made and written up by the finest scientist. But the two types, working together, will get farther than either one alone or both working separately. The point is that field work, office work and laboratory work should be carried on harmoniously, as parts of a plan, and not independently of each other.

There are certain definite objectives which present-day circumstances indicate. Among them are the design and manufacture of still better rail; the better care of rail. Improvement in rail joints and tie plates is important, having in mind the prevention of battered rail ends, the practicability of welding joints and the use of long rails, and the hardening of rail ends. The study of impact, the use of alloy metals and welding should be pursued as in the past, but with renewed enthusiasm because of new materials, tools and methods recently introduced, and because of the more exacting demands upon the track which our bridges carry. Water treatment, concrete and timber each has a large field of usefulness in railroad operation. All of these subjects and many others have had the benefit of splendid work by committees of this organization, but the exactions of the present and future demands upon roadway structures, coupled with the metallurgical and chemical knowledge now available, give point to special investigation.

I appreciate the handicaps under which we have all been working, but the time has come when we must strive for more refinement in manufacture and inspection of track material before it is placed in track, and then in the application and the care of it afterward.

The high speeds of to-day and higher speeds of tomorrow and the heavy axleloads of cars and locomotives require the following of plans and specifications with a precision that never before was so important, and careful inspection is needed to prevent variations from these plans and specifications that might result in damage or failure. When laying rail, and after it is laid, the greatest precaution should be exercised to avoid conditions that may cause overstressing in service.

It is not my thought that there is some magic by which things suddenly will be done, or that something will be discovered which has been overlooked, and that these things will bring a railway millenium. It is rather that we will be able to consolidate our gains and all obtain the benefits from what any and every single road has been doing along similar but individual lines.

The American railways should know a lot more than they do about several things pertaining to track and bridges; things that no one railway can afford to learn alone or can learn so well alone. The directing of experiments, and the insuring of correct interpretations when demonstrations are made, are so important that a common staff should do them for the common benefit. It is a real opportunity for joint effort and a challenge to the ability of the railways to coordinate in the interest of the whole industry.

You know it is strange how the same facts may be interpreted differently. The other day we in Chicago moved our clocks ahead an hour. A friend was telling me how he found himself eating breakfast when it seemed still dark, and his evening meal before the sun had set. Yet by a paradox he read in the morning paper at breakfast, by artificial light, how much daylight he had gained, and at dinner he read by daylight in the evening paper how much he had lost. Figure it out for yourselves. The secret may lie in the point of view, which illustrates the advantage of a neutral organization to interpret results.

All bureaus have certain inherent handicaps, but in a research bureau those handicaps could be reduced to the minimum. Of course, the success would depend, as that of all organizations depends, upon the Director or Administrator. He must not be afraid to permit some experiments even though complete success may be in doubt, yet he should be able to recognize a "perpetual motion" proposition when he sees one, and waste no time upon purely visionary schemes. I heard of a case where a railroad had difficulty gaining permission from a Bureau to move some light-weight freight cars to its own line for experimental use after they had been manufactured. The reason given was that they had hollow axles and light trucks. But the axles and trucks were strong. We are going to revise our ideas about things being strong, only if they are large and heavy. Standard equipment offered for interchange may properly be rejected if the coupler shanks are not 6 by 8 or 5 by 5 inches in dimensions, as the case may be, provided the material is standard also, but if stronger metals are used the rules will have to recognize some other yardstick as a measure of strength, and, of course, strength, hence safety, is what is here involved.

No talk to this group should end without a word on safety and what I have been saying suggests it. The record of the American railways proves that they have not let anything—not financial disaster; not the competitive urge; not speed nor any other expedience, divert their minds from safety in operation. All of us, and every other railway employee, may take just pride in the fact that 18 billion passenger miles were run last year without a fatal accident in a collision or derailment. That is the equivalent of handling safely, every man, woman and child in the United States a distance of about

150 miles. It is the more amazing when one considers the slaughter which is more or less nonchalantly perpetrated daily on the highways.

We are told by the National Safety Council that in the year 1935 there were 36,400 deaths, 107,000 permanent and 1,170,000 temporary disabilities resulting from highway accidents. The total economic loss to the Nation from these deaths and injuries, together with the property damage loss, amounted to more than one and one-half billion dollars.

Gentlemen of the American Railway Engineering Association, in your hands, is the great task of providing the roadway, bridges, track, signals and other structures over which the immense streams of railway commerce will flow. You and your predecessors have had an ever-changing problem as the locomotives and cars grew larger and heavier and the volume of traffic constantly increased. The changing requirements have been dealt with magnificently. Now you and your successors will have still different conditions to provide for. Faster trains and more of them, providing comfort and safety beyond those of any earlier period! You are not behind the procession, but well to the fore. Even after four full years of subnormal expenditures the properties in your care set a new all-time record for speed and safety. The same scientific principles, materials and methods which are being used in so rapidly advancing the types of locomotives and cars for which you are being asked to provide ultra modern track, will yield for you, and in your hands, standards of roadway and structures equally advanced. These constant changes and improvements serve to keep this organization very much alive and lively. So long as the Association lives up to its fine traditions, these very changes and constant improvements assure it of permanence and a perpetually youthful outlook, eager to embrace all new opportunities.

COMMITTEE REPORTS

REPORT OF COMMITTEE X—SIGNALS AND INTERLOCKING

C. H. Tillett, *Chairman;*
B. T. Anderson,
F. H. Bagley,
G. H. Dryden,
W. J. Eck,
W. H. Elliott,
P. M. Gault,
L. C. Heilman,
C. R. Hodgdon,
S. N. Mills,
J. C. Mock,
R. D. Moore,
H. G. Morgan,
J. A. Peabody,
F. W. Pfleging,
W. M. Post,
A. H. Rudd,
H. H. Orr, *Vice-Chairman;*
J. E. Saunders,
F. S. Schwinn,
E. G. Stradling,
C. A. Taylor,
W. M. Vandersluis,
F. B. Wiegand,
L. Wyant,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

1. Developments in railway signaling (Appendix A). Progress report.

2. The principal current activities of the Signal Section, by synopsis, supplemented with list and reference by number of adopted specifications, designs and principles of practices (Appendix B). Progress report.

The Committee on Signals and Interlocking,
C. H. Tillett, *Chairman.*

Appendix A

(1) DEVELOPMENTS IN RAILWAY SIGNALING

W. M. Post, Chairman, Sub-Committee; G. H. Dryden, W. J. Eck, F. B. Wiegand.

(A) Coded Signal Line and Rail Circuits

A system of operating signal line and rail circuits by means of coded or interrupted current as distinguished from the steady or continuous current formerly in use. It was first installed in 1926 with continuous train control and cab signaling.

Coded line and rail circuits may be applied in either steam or electric propulsion territory; where either wayside or cab signals are used, or where both wayside and cab signals are used; where two-block, three-indication signaling; three-block, four-indication signaling; or four-block, five-indication signaling is used; or it may be applied where the energy fed to the track circuit is direct current, alternating current, or both, or where frequency selective track relays have been required.

The coded line and rail circuits have many advantages, some of which are as follows:

1. Coded energy in either track or line circuits provides increased immunity to false energization from crosses, grounds, or any other foreign influence.

2. Increases track shunting sensitivity.

3. Provides three or four-block wayside or cab-signal control without the use of line wires, eliminating pole line or duct line signal control failures.

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Appendix B

(2) THE PRINCIPAL CURRENT ACTIVITIES OF THE SIGNAL SECTION, AAR, BY SYNOPSIS, SUPPLEMENTED WITH LIST AND REFERENCES BY NUMBER OF ADOPTED SPECIFICATIONS, DESIGNS AND PRINCIPLES OF SIGNALING PRACTICE

W. M. Vandersluis, Chairman, Sub-Committee; C. R. Hodgdon, J. C. Mock, F. S. Schwinn, E. G. Stradling.

CURRENT ACTIVITIES OF THE SIGNAL SECTION AAR

Since November, 1934 (As of November, 1935)

1. Printed and placed on sale an additional chapter of "American Railway Signaling Principles and Practices," entitled "Chapter XV—Automatic Block Systems."
2. Report on "Typical Methods of Effecting Economy and Energy Consumed in the Operation of Track Circuits."
3. Report on "Typical Methods of Effecting Economy and Energy Consumed in the Operation of Signal Circuits."
4. Study and analysis of "Steel, Bronze, and Zinc Taped Cables."
5. Report on "T. & T. Specification for Attaching Railroad Signal Wires and Cables to Communication Pole Lines."
6. Kept in touch and reported on the subject of "Automatic Train Control and Locomotive Cab Signals."
7. Report on investigation of use of "Reflecting Devices as a Substitute for Oil or Electric Lights."
8. Report on "Location of Home Signals with Respect to Railroad Grade Crossings."
9. Report on "Yard and Terminal Train Movements Expedited by Signaling."
10. Report on "Signal Protection for Light Traffic Railroads Crossing at Grade."
11. Report on "Train Operation—Single Track Versus Double Track."
12. Report on "Economics of Changing from Automatic Train Control to Automatic Cab Signals."
13. Report on revision of "Specification for Electric Lock."
14. Progress report on "Locking Tolerances for Rail Locking Devices used on Interlocked Drawbridges."
15. Report on "Methods of Protecting Railroads Crossing at Grade Where Traffic Conditions do not Justify an Interlocking Plant."
16. Report on "Direct Current Coded Track Circuit Control System."
17. Report on "Signaling for Gravity Classification Yards."
18. Report on "Use of 'Call-on' Signals."
19. Report on "Use of Exhausted Caustic Soda Battery Solution for Anti-Freeze Liquid in Railroad Motor Cars."
20. Report on "Development on Highway Crossing Protection."
21. Report on "Federal and State Activities."
22. Report on "Data on Nails," describing the origin of the "penny" system, a list of the standard nails in use, and sizes of various nails.
23. Report on "Protection against Lightning."

SPECIFICATIONS REVISED

	Old No.	*New No.*
Portable Alternating Current Ammeter	11221	112–35
Portable Alternating Current Voltmeter	11528	115–35
Mechanical Time Release	12831	128–35
Interlocking Lever Circuit Controller	13831	138–35
Car Retarder System	14731	147–35
Signal Glasses	6918	69–35
Direct Current Vibrating Highway Crossing Bell	4427	44–35
Low-Voltage Lightning Arrester	5215	52–35
Air-Cooled Transformer	83–34	83–35
Hard Fiber	1323	13–35

DRAWINGS REVISED

Crank and Jaw Pins	1010D	1010E
Guide Supports and Caps for Vertical Connections on Signals	1022	1022B
Guides for Vertical Connections on Signals	1023	1023B
Base for Bridge Mast	1036	1036B
Clamps for Base of Bridge Masts	1178	1178B
One-Arm Mechanical Ground Signal	1043B	1043C
Two-Arm Mechanical Ground Signal	1044B	1044C
Two-Way Horizontal Crank Stand Assembly with Three-Way Stand and Single Pin	1057B	1057C
Assembly of Transverse Pipe Carriers	1072	1072B
Foundation for Ground Mast Signals	1107A	1107B
Ladders for Bridge Mast Signals	1366	1366B
Ladder Clamps and Stays	1371	1371B
Thermometer	1375	1375B
Switch Adjustment Details	1390B	1390C
Switch Adjustment—Non-Insulated	1391	1391B
Switch Adjustment—Insulated	1392	1392B
Cast-Iron Washer	1458B	1458C
Ladders for Ground Masts	1583A	1583B
Ladder Parts	1585A	1585B

REQUISITES REVISED

Highway Crossing Signals.

FORM REVISED

Signal and Interlocking Unit Distribution	22	7050

INSTRUCTIONS REVISED

Installation, Maintenance and Operation of Nickel, Iron, Alkaline Storage Batteries.
Inspecting, Testing and Maintaining Alternating Current Relays.
Inspecting, Testing and Maintaining Direct Current Relays.

TABLE REVISED

Table of Signal and Interlocking Units.

NEW SPECIFICATIONS

	No.
Weatherproof Covering for Line Wire	163–35
Electric Color Position Light Signal	162–35
Capacitor for Power Factor Correction	160–35
Brass and High Tensile Strength Metals and Alloys for Binding Posts, Machine Screws, Nuts, Washers, etc., used in Signal Apparatus	159–35

NEW DRAWINGS

One-Way Pipe Carriers	1074A
Transverse Strap Pipe Carrier	1075A
Concrete Foundations for Air Lines	1081A
Socket Base for 5-Inch Mast	1250A
Short Pinnacles	1245A
Wide Sweep Cable Pinnacle	1251A
Bolts for Crossing Signs for 5-Inch Pipe	1655A
Switch Circuit Controller Connections	1254A
Switch Circuit Controller Lug	1255A
Switch Circuit Controller Rods	1256A

NEW INSTRUCTIONS

Signal Maintenance.

NEW FORM

Forecast of the Value of Signaling 24

NEW CONCLUSION

Signal Protection for Light Traffic Railroads Crossing at Grade.

NEW REFERENCE DATA TO BE INCLUDED IN THE MANUAL

Specification for Gray Iron Castings—A.S.T.M. Designation A48–32T.
Specification for Malleable Iron Castings—A.S.T.M. Designation A47–33.
Specification for Wrought Iron Bars—A.S.T.M. Designation A41–30.

NEW MISCELLANEOUS MATTER TO BE INCLUDED IN THE MANUAL

General Classification for Signal Interruptions.
Principles Applicable to Joint Signal Facilities.
Signaling for Gravity Classification Yard.

SPECIFICATIONS TO BE REMOVED FROM THE MANUAL

	No.
Gray Iron Castings	1630
Malleable Iron Castings	1730
Wrought Iron Bars	1830

DRAWINGS TO BE REMOVED FROM THE MANUAL

	No.
Strap Pipe Carrier	1071
Pipe Carrier Foundation	1109
Adjusting Crank	1199
Adjusting Crank and Assembly	1361
Switch Point Drilling	1299
Ladders for Bracket Posts	1372B
Turn In Pipe Run	1400
Leadaway	1402
Ladders for Bracket and Bridge Masts	1584A
Switch Box Connections	1223

MISCELLANEOUS MATTER TO BE REMOVED FROM THE MANUAL

Method for Comparing Operating Results Before and After an Improvement in Signaling Facilities.
Estimating Examples for Use in Determining the Economic Value of a Remotely Controlled Switch Installation.
Questions and Answers for Signal Maintainers.
Rules for Signal Maintenance.

REPORT OF SPECIAL COMMITTEE ON COMPLETE ROADWAY AND TRACK STRUCTURE

JOHN V. NEUBERT, *Chairman;*
C. J. GEYER,
EARL STIMSON,
C. H. TILLETT,
J. E. TEAL, *Vice-Chairman;*
A. R. WILSON,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subject:

(1) Complete roadway and track for various loads and traffic densities.

We wish to report progress.

The Committee recommends that this subject be continued.

THE SPECIAL COMMITTEE ON COMPLETE ROADWAY AND TRACK STRUCTURE,

JOHN V. NEUBERT, *Chairman.*

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REPORT OF COMMITTEE XXIII—SHOPS AND LOCOMOTIVE TERMINALS

J. M. Metcalf, *Chairman;*
W. J. Bennett,
H. G. Dalton,
A. G. Dorland,
E. A. Dougherty,
Benjamin Elkind,
C. E. Harris,
A. T. Hawk,
A. S. Kent,
E. E. Kimball,
L. P. Kimball,
J. S. Knight,
L. H. Laffoley,
H. C. Lorenz,
F. E. Morrow,
B. M. Murdock,
E. S. Pennebaker,
V. B. W. Poulsen,
J. S. McBride, *Vice-Chairman;*
W. A. Radspinner,
E. H. Roth,
J. C. Ryan,
L. K. Sillcox,
A. L. Smith,
H. W. Williams,
R. P. Winton,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual (Appendix A).

(2) Welding equipment installations as applied to Shops and Locomotive Terminals. Progress in study—No report.

(3) Adaptation of enginehouses, shops and engine terminal layouts for handling oil-electric locomotives and rail cars (Appendix B). Progress report.

(4) Power Plants (Appendix C). Progress report.

(5) Car wheel shops (Appendix D). Complete and presented as information.

The Committee on Shops and Locomotive Terminals,
J. M. Metcalf, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

L. P. Kimball, Chairman, Sub-Committee; J. M. Metcalf, J. S. McBride, A. T. Hawk.

(Note.—The following is intended as a revision and consolidation of the material now appearing in the 1929 Manual by Committee VI on pages 274 and 275, and by Committee XXIII on pages 1486 and 1487).

OIL HOUSES

General

State, municipal and other building requirements should be consulted, as the following recommendations are only supplemental thereto.

Location

Oil houses at terminals should be located not less than fifty (50) feet from adjacent buildings. They should be served with a track and located preferably near one end of the storehouse.

Construction

Oil houses should be built of fire-resistive materials, including steel sash with wire glass and all doors in partition walls should be approved fire doors controlled by fusible links. Tanks of sufficient capacity should be provided in the basement, except for gasoline and other high flashpoint oils, which should be located outside with the tanks placed

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underground. Vents for tanks in buildings should extend outside of building to a suitable height. Fuel oil storage tanks should be located outside and may be buried or placed above ground as local conditions warrant. If located above ground suitable dikes should be provided. A delivery counter, pumps, oil drums, storage rooms and bins for waste and similar material should be located on the first floor. For small stores where extensive facilities are not necessary, oil may be stored in a basement at one end of the storehouse with the counter, pumps, oil drums and waste on first floor. The oil house portion should be separated from the storehouse by a fire wall with protected openings.

Light and Heat

Lighting should be by electricity and controlled by switch outside of building. Lighting fixtures and lamps should be of vaporproof type. To maintain temperature at which heavy oils can be pumped, steam heat should be provided.

Oil Handling Equipment

Rectangular tanks are preferable for oil storage on account of requiring less floor space for a given capacity than cylindrical tanks.

Oils delivered in tank cars should be transferred from tank car direct to storage tanks. Gasoline and oils having a high flashpoint should be unloaded from the dome. For storing small quantities of oil, the use of rectangular steel tanks, arranged in batteries and located on first floor, is recommended. Such tanks should be equipped with barrel track and barrel cradles for handling oil from barrels to the tanks and with measuring pumps for delivering oil. Installation of mechanical hoist for handling barrels is recommended.

Oil tanks and piping in basement should be painted white to lighten up the basement and to readily show any leaks that may occur.

Delivery system from larger storage tanks in basement to the faucets should be such that the oil can be delivered quickly by means of approved self-measuring pumps located on first floor. There should be minimum dripping in connection with delivery system and all dripping must drain back to the storage tanks through screened outlets.

Sufficient space should be provided in the oil house for storage of waste, but preferably separated from the oil room by fire-resistive partition in which openings are protected by automatic self-closing fire doors. Provision should be made so that broken packages of loose waste be kept in metal boxes with weighted covers held in open position with a fusible link which will close cover in case of fire.

Where it is necessary to maintain mixing vats in oil houses and the machinery for reclaiming grease, a separate room should be provided for this purpose. Entrance from adjacent room should be protected by automatic fire door. If such facilities are large enough to justify it, separate building should be provided.

Fire Protection

A live steam line should be run to the oil storage space provided with necessary outlets and controlled by valve outside of building. Valve should be equipped with sign indicating that it is to be used for fire protection purposes only. An ample supply of foam extinguishers must be maintained, also sand in barrels and pails.

PAINT STORES

Where practicable this facility should be part of the oil house and where impracticable a separate fire-resistive building should be provided, located conveniently to the paint shop. Where the paint store is part of the oil house, it should be separated from the oil storage portion with a fire wall.

The shelving or bins should be of steel or other non-combustible material.

Cylindrical tanks should be used for storage of paints which have to be kept mixed and tanks in which paints are stored should be equipped with agitators and should be evaporation proof.

Appendix B

(3) ADAPTATION OF ENGINEHOUSES, SHOPS AND ENGINE TERMINAL LAYOUTS FOR HANDLING OIL-ELECTRIC LOCOMOTIVES AND RAIL CARS

H. G. Dalton, Chairman, Sub-Committee; W. J. Bennett, E. A. Dougherty, Benjamin Elkind, A. T. Hawk, A. S. Kent, L. P. Kimball, J. S. Knight, B. M. Murdock, W. A. Radspinner.

The provision of facilities for handling and repairing oil-electric locomotives is a problem of growing importance with the increasing use and size of such power units. Your Committee this year submits as a progress report a study of the arrangements made by one road, which has in operation four streamlined articulated 3 and 4-car trains. The power plant in each of these trains consists of a Diesel oil engine direct connected to an electric generator for propelling the train through two 300 HP motors on the two axles of the leading truck.

In connection with servicing oil-electric power units it was suggested that drop and inspection pit facilities be provided at terminals where these oil-electric power units are to be serviced or have their layover period.

For servicing such equipment a drop pit of ample dimensions has been provided, equipped with an electrically operated drop pit table of sufficient capacity to handle such weight as imposed upon it by the front end of forward car and power truck. Two hand-operated overhead cranes are installed to support the holding arms, two holding arms on each crane to be placed under the pads on the end of each car on either side or one set of arms to support the front end of forward car opposite the power truck while the power truck is lowered by means of the drop pit table and taken out on an adjacent track and then lifted to the track level by means of an electrically operated overhead crane.

The layout is arranged so that the train is serviced with the power truck over the drop pit and the inspection pit extends from the drop pit to the end of the train, making the overall length of the drop pit and inspection pit the full length of the train. The drop and inspection pit facilities are conveniently located at the point where such train is to be regularly parked at the terminal coach yard.

FUEL OIL FACILITIES

Fuel oil facilities consisting of an underground storage tank, with fuel oil capacity for 30 days' supply, have been provided together with an oil unloading device, fuel oil pump and necessary hose connections for filling the storage tanks, mounted under the cars of the trains.

HEATER BOILER WATER SUPPLY

A tank for collecting condensate from the coach yard heating system is provided so that water for the heating boiler can be pumped into the storage tanks, supplying distilled water to the train heating plant by means of an electrically driven pump.

Appendix C

(4) POWER PLANTS

E. H. Roth, Chairman, Sub-Committee; Benjamin Elkind, C. E. Harris, A. T. Hawk, E. E. Kimball, L. H. Laffoley, H. C. Lorenz, F. E. Morrow, B. M. Murdock, E. S. Pennebaker, W. A. Radspinner, H. W. Williams.

This year's work is confined to the study of major power plants at railroad terminals generating steam for all local demands, except that electric power is obtained from outside sources.

The location of such plants with reference to the terminal is such as to give the best conditions in regard to the distribution of steam heat and air lines to locomotive shops, erecting and machine shops, boiler, tin and tank shops, blacksmith shops, coach shops, paint and upholstering shops, wheel and air brake shops, planing mill, freight car shops, storehouses, office buildings, and enginehouses, as well as convenience to tracks for the plant fuel supply and ash disposal, if any. This plant is usually a combination steel, concrete, and brick structure, in other words, as near fireproof as is possible.

The steam generating plant usually consists of sufficient boilers for the present demands and space for such additional facilities as may be needed for the future expansion of the local terminal and shops. Where the fuel is coal, boilers should be stoker-fired; traveling grates for free burning coal; or retort type for coking coal; the coal to be handled by machinery, elevators, and conveyors from track hoppers where cars can be unloaded with the least expense. The ash should be handled by machinery (chain conveyor, steam or vacuum system) to discharge into receiving hopper or directly into cars. The boiler room should be equipped with modern appliances to check performance and for economic operation, the boilers to be operated on forced draft and the waste gases removed by a stack of brick or concrete construction, or induced draft.

The economic production of steam and of power from fuels is controlled by three fundamental factors: first, the fuels themselves and their characteristics; second, the plant equipment by which the energy latent in the fuel is transferred to the steam; and third, the manner in which this operation is carried on.

These three factors, while varying for different plants and different fuels, are closely inter-related, plant operation being controlled not only by the skill of the operating force, but by the limitations of the equipment and the characteristics of the fuel used. Thus, while it is not possible entirely to separate these three factors for the consideration of anyone, it is possible to consider fuels in relation to their effect on the others and in so doing to derive information of considerable value.

The selection from the fuels commercially available to any particular plant of the one that will most economically produce steam, considering both price and usability, is the first and most important single factor in the economy of plant production. The efficient utilization in the plant of the fuel selected is, however, of vital importance also and it is only by proper fuel selection seconded by proper utilization that the maximum economy in steam production can be obtained. This requires a working knowledge, not only of the various fuel types and their different properties, chemical and physical, but also of the effect of these properties on their efficient utilization in the plant in question.

Fuels, at first glance, appear quite diverse in character. Some are solid and must be burned on grates, others are gases and are pumped into the furnace chamber and burned in suspension. Volatile matter, ash fusion temperature, fixed carbon, heating value, only serve to confuse both the selection and utilization of fuels unless these operations are approached with some knowledge of what these properties mean in terms of the fuel's efficient use.

Certain fundamental differences and variations do exist, of course, not only between different fuel types, but between the various grades and qualities of the same type and out of these differences and variations have sprung the different methods of burning fuels and the different types of equipment for this process.

The fuels used in the production of steam and power are divided into three general types: solid, liquid and gaseous. The principal fuels in general use are arranged in Table 1 according to their physical state, and are further classified as primary fuels (fuels obtained from the earth in their natural state), and as derived or manufactured fuels.

TABLE 1

BASIC CLASSIFICATION OF FUELS

	Primary	*Secondary or Manufactured*	
Solid	Anthracite Coal Bituminous Coal Lignite Peat Wood	Powdered Coal Coke Charcoal Briquettes	
Liquid	Petroleum	Petroleum Distillates Petroleum Residuums Alcohol Colloidal Fuels	
Gaseous	Natural Gas	Illuminating Gas Water Gas Oil Gas Industrial Gases	Blast Furnace Coke Oven Producer

In addition to the fuels thus classified, there is a group which might be called waste or by-product fuels. These include the tars, acid sludges, soda bottoms, etc. The majority of these are refuse from the petroleum refining or gas-making processes, and have, until recently, been considered as commercially valueless. Bituminous coal is overwhelmingly the most important fuel from the viewpoint of quantity consumed.

The power resources of the United States of America in heat equivalents have been estimated as follows:

Bituminous Coal	55%
Anthracite Coal	10%
Oil	18%
Fire Wood	6%
Natural Gas	4%
Water Power	7%

Factors which influence steam power plant economy have been improved at least 25 per cent during the past decade. These gains have been brought about mainly by improvements in the boiler room. Modern practice has improved not only the efficiency, but also the steaming capacity of boiler plants. There is a general trend in all types of steam power plants toward higher pressures and temperatures. These higher pressures and temperatures are particularly advantageous for plants where use can be made of exhaust steam for heating or other purposes and where condensing operation is impractical.

Higher feed water temperatures and improvements in furnace design and in fuel-burning equipment have also contributed greatly to improved fuel economy. Savings have been effected by educating the various department managements not to waste power; to use exhaust steam in place of live steam and hot water in place of steam where practical. Steam evaporating surfaces are being arranged to better advantage. Furnace volumes are being modified to make operation at higher ratings possible.

Improved power plant economy is being secured by designs to suit the fuel available: by economical fuel-handling methods; by clean feed water at high temperature; by boiler surfaces free from soot and scale; boiler settings and baffles free from leaks; by properly insulating piping and other equipment which lose heat by radiation; by the best utilization of exhaust steam; and by sufficient instruments for the purpose of keeping a careful check on and record of plant performance.

Suitable instruments to record plant performance are being used very generally in modern power plants. Practically every progressive power plant is equipped not only with indicating and recording gages to record steam pressures on boilers, headers, and near engine or turbine throttle, but also with recording thermometers to measure the temperatures or feed water, flue gases, and steam; means for metering steam generated by boilers and steam used for different purposes; means for measuring feed water and fuel used; draft gages; CO_2 recorders or other instruments for analyzing flue gases; electrical instruments; also special instruments and meters to suit local conditions. Centralized systems of combustion control are being installed in most of the newer power plants and special devices are being installed to reduce to a minimum physical exertion on the part of the operating force, with incident reduction in labor costs.

Power Plant Design.—The objectives to be sought in a power plant are reliability of operation and an economical product, whether that product is steam, electricity, or mechanical power. In other words the plant must be dependable and commercially efficient to justify the investment.

The cost of the product per unit output from a power plant depends upon the fuel used; the cost of repairs and replacements; the amount paid for operating labor; and fixed charges. The fixed charges (interest, rent, depreciation, obsolescence, taxes, and insurance) in most of the modern power plants have been going up while the cost of fuel and operating labor has been going down. In some of the large steam-electric power plants, the fuel and labor cost per unit of output has been cut in two during the past ten years and in many plants the cost of fuel per unit of output is only about one-half the fixed charges.

In designing a power plant or in expending funds for improvements, care must be taken that the gain in economy justifies the investment. The load factor or the sustained use of power influences power plant design. The higher the load factor, the greater is the justification for high investment costs to increase fuel economy.

The cost of buildings for power plants varies at present from 15 per cent to 35 per cent of the total cost of the plant. Accordingly, care must be taken to reduce the volume of power plant buildings to a minimum. Present practice is to place breechings on roofs of buildings to reduce roof heights and to make most advantageous use of space for offices, auxiliary rooms, oil storage, etc.

The design of the power plant should be fitted to the fuel which can be obtained to the best advantage. In designing equipment for a certain fuel care must be taken that the continuity of the fuel supply is assured and that the primary preparation methods will insure uniform quality of fuel. Smokeless and efficient combustion can be obtained with numerous fuels if the combustion chambers are properly designed.

Furnaces should be designed so that the boilers will operate at fairly high ratings. High ratings, however, are a matter of investment and must be considered together with other factors.

Even the small plant will find automatic or semi-automatic stokers economical in both labor and fuel. In selecting a stoker consideration should be given to the fuel used, the character of the load, draft available, and size of combustion space.

The use of powdered fuel has produced material savings in large power plants. However, recent improvements in mechanical stokers do not justify at the present time any extensive use of powdered fuel for small power plants.

High pressure steam accumulators are being used to an increasing extent to take care of fluctuations in steam demands. This type of equipment should prove advantageous for plants with limited furnace volume.

Much may be said concerning the design of power plants at railroad terminals. The demands in the northern sections of the country for heating purposes are much greater than through the southern sections. Types of fuels in different sections are also the controlling factor as to the type of boiler to be used.

The question of what type of power plant is best can never be answered twice in a row; what is meat for one plant might be poison for a dozen others.

Appendix D

(5) CAR WHEEL SHOPS

J. S. McBride, Chairman, Sub-Committee; H. G. Dalton, C. E. Harris, A. T. Hawk, A. S. Kent, L. H. Laffoley, H. C. Lorenz, F. E. Morrow, E. S. Pennebaker, V. B. W. Poulson, L. K. Sillcox.

In considering the subject of Car Wheel Shops, it was the view of your Committee that a study of a recently constructed, up-to-date shop with illustrations, showing how the problems of layout and design have been worked out in a particular case, would be more informative and valuable than an abstract discussion. It accordingly presents such a study, as information.

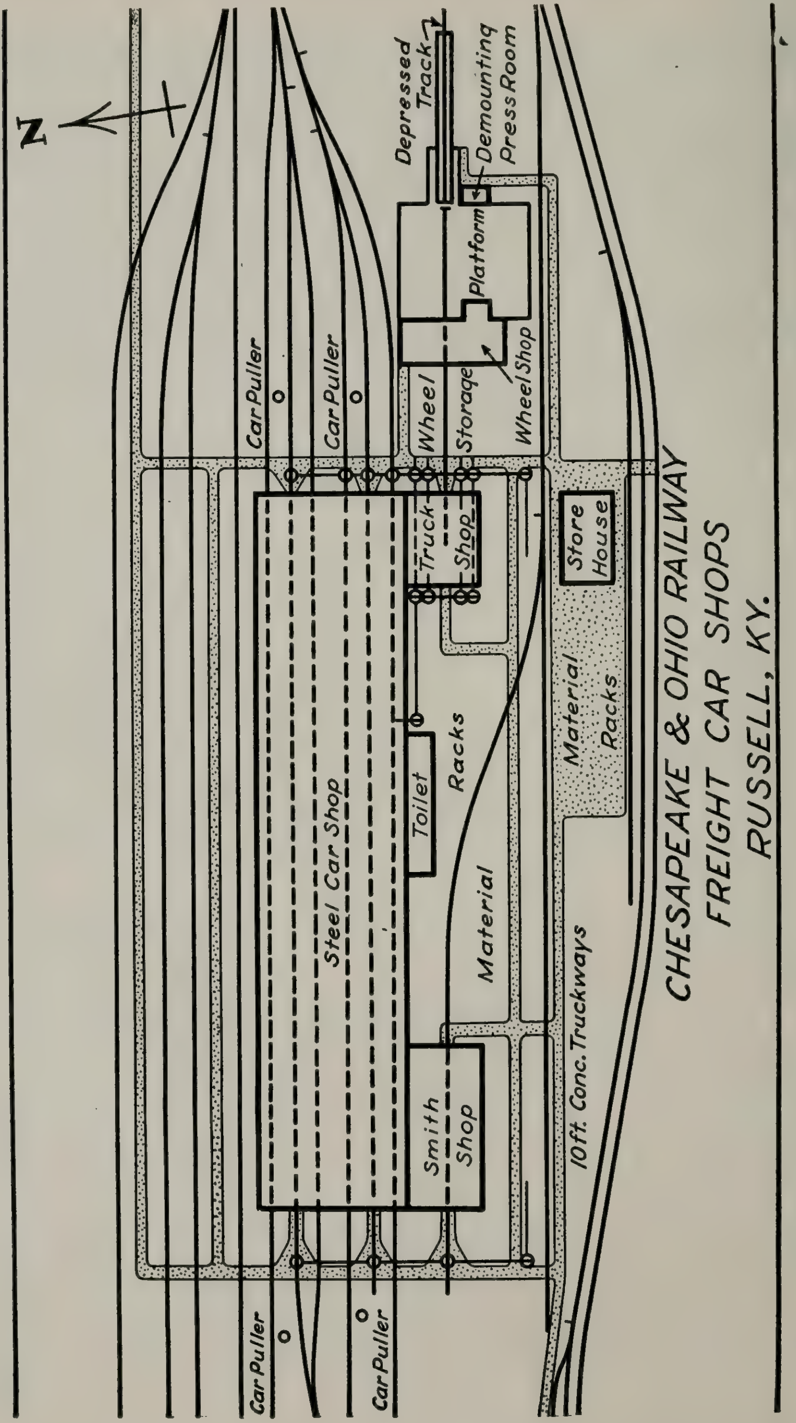
A plan of the modern freight car shop layout of the Chesapeake and Ohio Railway at Russell, Ky., showing the location of the car wheel shop with relation to the other facilities is herewith submitted, also a plan of the wheel shop itself with its machinery and equipment.

Car wheel work is performed in an independent building, the space between the wheel shop and truck shop being utilized for wheel storage tracks. The truck shop adjoins the main car shop.

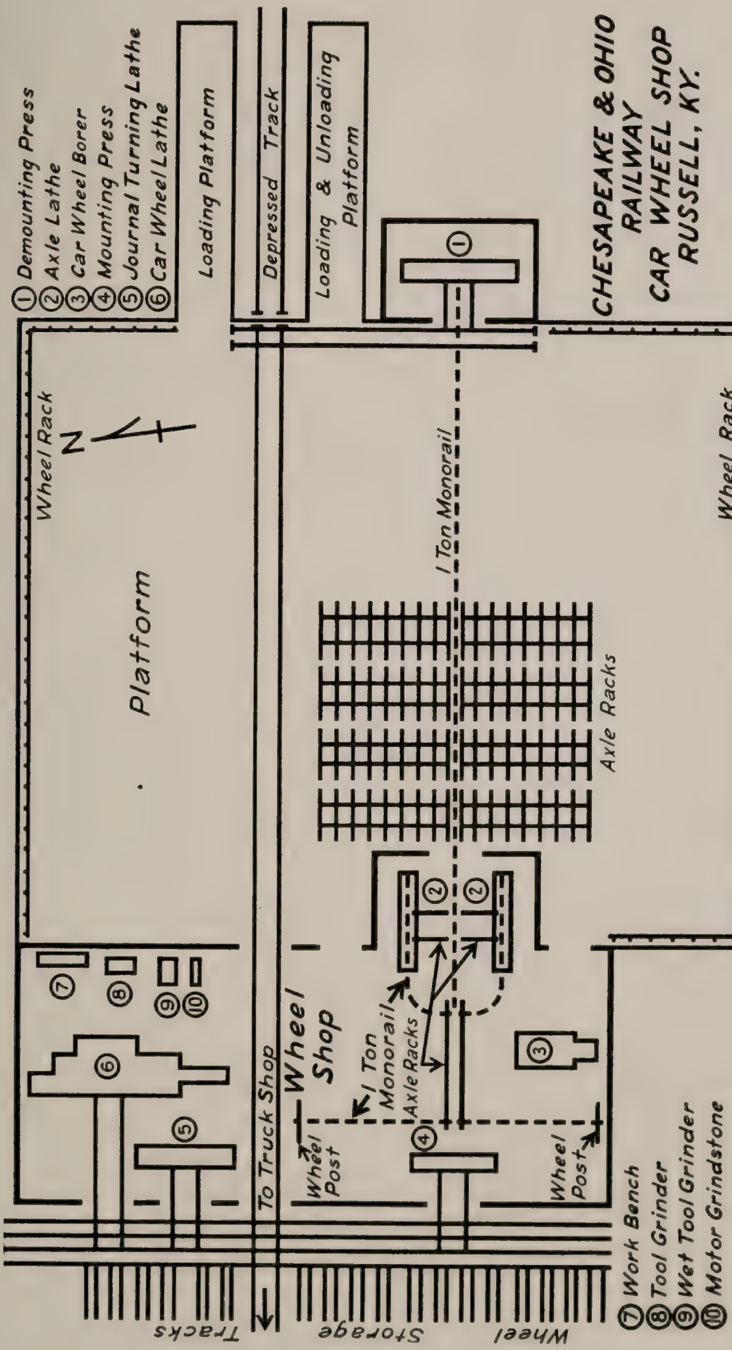
The wheel shop handles wheels for the freight cars repaired at this plant and some wheels for other repair yards. The latter enter and leave on the depressed track.

Wheels that are not to be demounted are taken from the truck shop or storage tracks to the journal turning lathe (5) and/or car wheel lathe (6) in north end of wheel shop. Wheels are rolled onto a dolly that operates on one of the narrow-gage tracks across the ends of the storage tracks, so that wheels can be moved from any storage track to any of the tracks leading into the building. After the necessary work is performed the wheels are returned the same way.

Wheels that are to be demounted are rolled on the track to the east end of the platform and taken to the demounting press (1) on a dolly that operates on another narrow-gage track. New and demounted wheels and axles are stored on the platform and in turn are taken to the car wheel borer (3) or axle lathes (2), the wheels being rolled in and the axles handled by mono-rail cranes. After turning and boring the wheels and axles are assembled on a rack, then pass through the mounting press (4) to the storage tracks for use in the truck shop or at outside points.



CHESAPEAKE & OHIO RAILWAY
FREIGHT CAR SHOPS
RUSSELL, KY.



CHESAPEAKE & OHIO RAILWAY CAR WHEEL SHOP RUSSELL, KY.

REPORT OF COMMITTEE XX—UNIFORM GENERAL CONTRACT FORMS

F. L. Nicholson, *Chairman;*
E. H. Barnhart,
W. H. Brameld,
*R. P. Eubank,
W. D. Faucette,
J. P. Hanley,
B. Herman,
J. C. Irwin,
J. S. Lillie,
S. L. Mapes,
A. A. Miller,
O. K. Morgan,
C. B. Niehaus,
H. A. Palmer,
W. M. Post,
W. G. Nusz, *Vice-Chairman;*
S. S. Roberts,
Chas. Silliman,
Huntington Smith,
W. R. Swatosh,
J. S. Thorp,
*C. A. Wilson,
Committee.

---

* Deceased.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual.—The Committee is presenting certain changes in various adopted forms, in the nature of editing, with the view to uniformity, simplification and convenience in use. The Chairman of the Sub-Committee will present these changes for your adoption, with the recommendation that such changes be made in the forms now in the Manual, to which they apply, at the time of the next printing (Appendix A).

(2) Form of Agreement with Public Authorities for Highway Grade Crossing Elimination or Separation, collaborating with Committee IX—Highways. This subject was assigned prior to the Federal Government activities now in progress for grade crossing separation and in view of such Federal interest, the Committee believes that no good purpose can be accomplished at this time, either by a report or a continued study of the subject; we, therefore, recommend that the subject be discontinued.

(3) Form of Agreement for Cab Stand Privileges. Tentative form of Agreement has been prepared and is submitted as information (Appendix B).

(4) Form of Agreement for Store-Door Delivery. The tentative form of Agreement presented in Appendix C embodies, in the judgment of the Committee, the essential terms for such an agreement and is submitted as information. Members of the Association interested in such a form are urged to give to the Sub-Committee the advantage of their criticisms or suggestions.

The Committee on Uniform General Contract Forms,
F. L. Nicholson, *Chairman.*

Bulletin 381, November, 1935.

Charles Alfred Wilson

With deep sorrow this Committee records the death of Charles Alfred Wilson at his home in Wyoming, Cincinnati, Ohio, June third, 1935.

Whereas, Mr. Wilson, a Promoter and Charter Member of this Association, served faithfully as a member of this Committee from March–1909 until the time of his death, and as Vice-Chairman during the years 1913 to 1922, conscientiously attending nearly all of its meetings during his membership, faithfully performing services required and won the high regard, confidence and affection of the members of this Committee by reason of his friendly, sociable manner, his earnestness in the service, his highly judicial temperament and his contribution of valuable advice resulting from his long experience in many important engineering and operating positions in railroad service; therefore, it is

Resolved, in recognition of his attainments, the high regard held for him by its members throughout these twenty-six years, and the value of his services to the Committee, that this Memoir be adopted as a record of our sense of the great loss we have sustained. It is further

Resolved, that this Memoir be included in the Annual Report of this Committee for publication in the Proceedings of the Association.

Adopted at the meeting of Committee XX, New York City, September 30, 1935.

Roland P. Eubank

With sorrow and a sense of loss this Committee records the death of our esteemed member and co-worker, Roland P. Eubank, in Richmond, Virginia, October fourteenth, 1935.

Mr. Eubank became a member of the Association February 23d, 1929, and a member of Committee XX in 1930 and served thereon until his death. He served as Chairman of Sub-Committee in 1934 and 1935, having in hand the preparation of "Form of Conveyance of Title, Granting the Right to Construct and Maintain Buildings over Railway Property."

Mr. Eubank was one of the Committee's most active members, ready at all times to respond to calls upon his time and experience; he was highly esteemed by the members of this committee and his passing will be a distinct loss to the Association.

Appendix A

(1) REVISION OF MANUAL

O. K. Morgan, Chairman, Sub-Committee; E. H. Barnhart, J. S. Lillie, W. G. Nusz, J. S. Thorp, C. A. Wilson.

It is recommended certain changes be made in the various adopted Forms along the following lines:

1. Simplification of titles of six adopted forms.

2. More uniformity of wording in the opening paragraph of each form in describing the parties to the agreement. The changes consist of naming the Railway Company first, describing it as a corporation, etc., and the other party second.

3. Greater uniformity in the contract forms where two railways are parties to the agreement. Three recently adopted forms use "A" Company and "B" Company to aid in understanding the contract. It is proposed to correct three additional forms by the insertion of "A" Company and "B" Company in the blank spaces; printing will also be simplified.

4. Substitution of a uniform Arbitration paragraph for the diverse wording of eight existing paragraphs; one of which calls for three arbitrators; seven call for a sole arbitrator and some forms provide for the Court to appoint the arbitrator if the parties cannot agree. The proposed form provides for a sole arbitrator, Court appointment if the parties cannot agree, and for the allocation of the expense.

5. A large number of existing forms have subheads at the beginning of the paragraph, which are a great convenience to the user. It is proposed to supply subheads to the remaining ten forms and add to their convenience and also make for uniformity.

6. The executory paragraph of existing forms differ widely in wording, without any valid reason. It is proposed to make this clause uniform in the various forms.

Recommendations are as follows:

Appendix B

(3) FORM OF AGREEMENT FOR CAB STAND PRIVILEGES

E. H. Barnhart, Chairman, Sub-Committee; W. H. Brameld, R. P. Eubank, W. D. Faucette, J. C. Irwin, H. A. Palmer.

Your Committee submits the following tentative draft of Agreement as information:

THIS AGREEMENT, made this .... day of .... 19...., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company, and (a), hereinafter called the Cab Company.

WITNESSETH:

THAT in consideration of the covenants and agreements herein contained it is mutually agreed as follows:

1. The Railway Company agrees to give to the Cab Company so far as it lawfully may, the sole and exclusive privilege of maintaining a public cab stand and/or baggage transfer on its premises at .... and of soliciting passengers and/or baggage on the grounds and platforms at said location, including the right to check baggage through from residences and hotels to destination, subject to the rules and regulations of the Railway Company.

2. The Railway Company agrees to permit the Cab Company to park on its property a sufficient number of cabs for transportation of passengers and others at a point or points to be designated from time to time by the Railway Company, but nothing herein contained shall make it obligatory upon the Railway Company to furnish such parking space.

3. The Cab Company agrees to provide for regular service at said location suitable cabs and/or conveyances for baggage to fully accommodate all reasonable demands of patrons and passengers of the Railway Company, and that it will at all times keep them in proper repair.

4. The Cab Company agrees to provide suitable cabs and/or conveyances for baggage from said location to other stations, for account of the Railway Company, at stipulated rates to be submitted by the Cab Company to the Railway Company and approved by it provided for in paragraph 6, prior to the effective date of this agreement.

5. The Cab Company agrees that its agents and employees shall not be considered employees or agents of the Railway Company, that at all times its agents and employees will conduct themselves in an orderly and respectful manner when soliciting business from patrons or passengers of the Railway Company, and when on Railway property will be subject to such rules and regulations as the Railway Company may from time to time prescribe.

6. The Cab Company agrees that, from time to time, or when requested by the Railway Company, it will submit to the Railway Company a schedule of its rates for transfer of passengers and for baggage and that it, its agents or employees will not collect or charge patrons or passengers of the Railway Company rates in excess of the schedule approved by the Railway Company, or regular rates of recognized cab companies in the same zone or fares prescribed by law.

7. The Cab Company agrees that neither it, its agents or employees will act as solicitors for any hotel, restaurant, lodging house or any business, or in any way endeavor to prejudice any patron or passenger of the Railway Company for or against any hotel, restaurant, lodging house or business, nor will they or any of them distribute or circulate any form of advertising whatsoever in behalf of any hotel, restaurant, lodging house or business.

8. The Cab Company agrees that it will keep a record of the disposition of all baggage received from the Railway Company for delivery and agrees that all such baggage shall be considered in good condition unless a "bad order" receipt is accepted by the Railway Company. All claims of patrons or passengers upon the Cab Company for loss or damage, other than heretofore specified, will be handled by the Cab Company direct with the claimants and they will assume all costs thereof. The Cab Company agrees to waybill all baggage collected by it for delivery to the Railway Company and will obtain from the Railway Company a receipt for all such baggage delivered to it. The Cab Company will be responsible for all loss and damage to baggage collected by it which has not been receipted for by the Railway Company. On baggage billed through from residence or hotel to destination, in the event of loss or damage, when the responsibility for such loss or damage cannot be ascertained, and is not already hereinbefore provided for, the Cab Company shall contribute to any payment made, cost, expense or injury suffered by the Railway Company or any other carrier, on account of such loss or damage, in the proportion that the charge of the transfer of such piece of baggage bears to the total revenue received by the Railway Company and other carrier from the transportation of said baggage and passengers accompanying same.

9. The Cab Company agrees to indemnify and hold harmless the Railway Company for loss, damage or injury from any act or omission of the Cab Company, its agents or employees, to the property of the Railway Company to the person or property of patrons or passengers of the Railway Company or any claim filed against the Railway Company, resulting from acts of the Cab Company, its agents or employees. The Cab Company agrees to indemnify and hold harmless the Railway Company from any claim for damage arising from injuries to any of its employees while engaged in handling the transfer business, whether caused by acts of employees of Railway Company, condition of buildings or platforms of the Railway Company or any cause whatsoever.

10. The Cab Company agrees to pay to the Railway Company for said privilege the sum of .... Dollars ($........) payable monthly in advance before the 10th day of the month succeeding which the payment becomes due, such payment to be made at the principal office of the Railway Company or at such other point the Railway Company may from time to time direct.

11. This agreement shall become effective from on/after the .... day of .... 19.... and shall continue from month to month until terminated as follows:

(a) By either party giving the other thirty days written notice prior to first of any calendar month, it being the intention that either party will have a full calendar month's notice.

(b) By the Railway Company, if the Cab Company should at any time fail in the judgment of the Railway Company, to fully perform any or all of its obligations under this agreement, giving the Cab Company or its agent on the premises ten days written notice. The Cab Company upon receiving such notice agrees to remove its vehicles and property from the premises and discontinue use of Railway Company property.

(c) By the Railway Company, if the Cab Company is in arrears in its rental payments more than three months, unless deferred payments are arranged by mutual agreement between the Railway Company and the Cab Company.

(d) By the Railway Company when the Cab Company sublets, without the consent of the Railway Company, any of the privileges hereby granted to the Cab Company.

12. It is mutually agreed that in the event of the termination of this agreement in accordance with paragraph 11, nothing shall be construed to relieve the Cab Company of any of its obligations in paragraph 9, which may have occurred prior to the termination of this agreement.

13. The Cab Company agrees that it will not, without the written consent of the Railway Company, assign or sublet any of the privileges herein granted.

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

Attest:........................ ....Company
Secretary

By.......................................

Attest:........................ ....Company
Secretary

By.......................................

(a) Insert name of company followed by "a corporation organized and existing under the laws of the State of ...." or "a partnership" or "individual," etc.

Appendix C

(4) FORM OF AGREEMENT FOR STORE-DOOR DELIVERY

W. G. Nusz, Chairman, Sub-Committee; J. S. Lillie, S. L. Mapes, A. A. Miller, S. S. Roberts, Huntington Smith, C. A. Wilson.

In meeting its assignment your Committee has collected, considered, and given weight to much information. Among other things, there were submitted by different railroads many forms of agreement for store-door delivery, some of which are in use and others of which are intended for use in the near future. Also advantage has been had of contact with the Western General Managers' Association through its sub-committee which has recently prepared and submitted a proposed form of agreement for store-door delivery.

The proposed form of agreement herewith presented for your information embodies, in the judgment of your Committee, the essential terms, as gathered from all of the available sources of information.

Each member of the Association who is interested in such a form is urged to give your Committee the advantage of his criticisms and suggestions.

FORM OF AGREEMENT FOR STORE DOOR DELIVERY—1936

THIS AGREEMENT, made this .... day of .... 19...., by and between the .... Railway Company, a corporation organized and existing under the laws of the State of .... hereinafter called the "Railway Company" and ....[a]......., hereinafter called the "Contractor" to be addressed at ...., City of ...., State of ....;..

WITNESSETH:

WHEREAS, the Railway Company has put into effect and may from time to time hereafter put into effect, certain tariffs covering "Pick Up and Delivery Service of Less Than Carload Freight" in and near the City of ...., State of ....; under the terms of which it will transport by truck or other highway vehicle, certain of such freight between the warehouses, factories, stores or similar places of business of sundry shippers or receivers of freight, hereinafter sometimes called, "Shippers Premises" located at ...., State of.................., within the area designated in the applicable tariffs, and its freight station or cars hereinafter sometimes called "Railway Company's Freight Station," and

WHEREAS, the Contractor desires to enter into a contract with the Railway Company to perform such trucking transportation for the Railway Company, and,

WHEREAS, the parties hereto have agreed upon the performance by the Contractor of so much of said service as the Railway Company may from time to time request the Contractor to handle as herein provided;

NOW, THEREFORE, in consideration of the covenants and agreements herein contained, to be performed by the parties hereto and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

THE CONTRACTOR COVENANTS AND AGREES:

Contractor's Equipment

1. To provide and maintain in good repair and first-class condition, at the Contractor's sole cost and expense, adequate equipment and employ and maintain adequate forces, including delivery clerk, if necessary, all to the satisfaction of the Railway Company, for the prompt movement of such freight between Shippers' Premises and the Railway Company's freight station as the Railway Company may direct, and upon notice from, and within the hours designated by the Railway Company, to load and haul all such freight from or to the Railway Company's said freight station or Shippers' Premises, and unload said freight promptly, all in accordance with the Railway Company's published tariffs and regulations.

Delivery of Freight

2. Should the Contractor be unable to deliver any freight the day it is loaded on his vehicle or vehicles, or in time to be handled in the regular course of the day's business, the Contractor shall, at his risk, store such vehicle or vehicles in a safe place and deliver the freight at the opening of business on the next business day.

3. To provide dray tickets and all other stationery required on account of said "Pick Up and Delivery Service" to the satisfaction of the Railway Company.

4. All loading and unloading of freight on or from vehicles of the Contractor shall be done by or at the sole expense and risk of the Contractor.

Freight in Contractor's Possession

5. Freight shall be deemed to be in the possession of the Contractor from the time the Contractor shall commence loading same on its vehicle or vehicles at the Railway Company's freight station until delivery to the Consignee and proper receipt obtained therefor, and/or from the time it shall be received by the Contractor from any Shipper until delivered by the Contractor at the Railway Company's freight station accepted by the Railway Company and proper receipt given therefor. The provisions of this paragraph shall include all freight while being loaded upon or unloaded from any vehicle of the Contractor in all cases where such loading or unloading is performed wholly or in part by the Contractor or the Contractor's agents, servants or employees.

---

[a] "Contractor" should be properly identified as a "Corporation organized and existing under the laws of a State", a co-partnership, an individual, etc.

Protection of Freight

6. Any vehicle containing freight shall be protected by having the doors thereof securely closed or sealed, except in cases where the freight therein contained is of such a nature as to require that it shall protrude through the end doors or through the sides or top of said vehicle, in which event the Contractor shall take all such other necessary steps and precautions as to prevent loss or damage to any of the freight in such vehicle as may be caused by the weather or on account of articles falling from such vehicles or on account of pilferage of any of such freight therefrom.

Collection of Freight Charges

7. To collect at the direction of and within the time specified by the Railway Company all charges on inbound freight and all invoices on C.O.D. shipments, as shown on freight bills, and likewise to collect all charges from consignors on outbound freight billed prepaid. The Contractor shall furnish receipts for all sums so collected on forms and in the manner prescribed by the Railway Company. The Contractor shall, within twenty-four hours after collection (Sundays and legal holidays excluded) pay to the Railway Company's agent authorized to receive it at the said place, all sums so required to be collected by him. The Contractor shall promptly return, without charge to the Railway Company, all C.O.D. inbound freight on which the Contractor shall be unable to make such collections. The Contractor shall in no event collect compensation for said transportation and delivery service other than that prescribed in the then effective tariffs of the Railway Company.

Bills of Lading and Delivery Orders

8. To promptly deliver to the Railway Company's said agent any and all original bills of lading and/or delivery orders surrendered by any Consignees on delivery of any freight handled hereunder, and to take receipts from all Consignees for shipments delivered and, if requested, to deliver such receipts to the Railway Company. To give receipts to Consignors for all shipments received and to furnish the Railway Company with duplicates thereof. The Railway Company shall give receipts to the Contractor upon delivery of all freight to the Railway Company and the Contractor shall receipt to the Railway Company for all freight delivered to the Contractor by the Railway Company. All such receipts shall be given or taken in accordance with the Railway Company's instructions and regulations and on forms prescribed by it, and shall carry notations as to the apparent condition of the freight, at the time of receipt or delivery if in other than good condition.

Inspection of Accounts

9. To maintain and preserve complete and accurate books, accounts and records, covering the service herein provided for and to permit a full and complete examination thereof, together with any other of the Contractor's books, accounts and records pertaining to the service herein provided for at all times by authorized representatives of the Railway Company.

Permits and Licenses

10. To secure any and all certificates, permits or licenses required by law, necessary for or in connection with the operation of the service provided for in this agreement.

Compliance With Laws

11. The Contractor, its agents, servants and employees shall comply with and obey all Federal, State and Municipal laws and ordinances and all orders, rules and regulations of administrative or governmental bodies or commissions having jurisdiction, applicable to the transportation or handling of freight under this agreement, or otherwise pertaining to freight to be transported or handled by the Contractor hereunder; and the Contractor shall protect, indemnify and save harmless the Railway Company from and against any and all fines, penalties, damage, loss, cost and expense of any kind or character whatsoever (including attorney's fees, costs of investigation and all other similar costs) arising directly or indirectly out of the violation by the Contractor, its agents or employees, or any of them, of the provisions of this paragraph.

Form of Payment of Freight Charges

12. All collections shall be made in cash unless otherwise authorized in writing by the Railway Company. The Contractor in no case shall be liable for the payment of checks or forms of payment other than cash accepted by him under such written authorization.

Charges to Other Carriers

13. In the event the Contractor should charge any other Railway Company in the City of .... for like service, rates lower than the rates herein set forth, the Contractor will forthwith reduce the rates herein set forth so that they shall at no time be higher than those charged any other Railway Company for like service.

Damage and Injury

14. To protect, indemnify and hold harmless the Railway Company from and against any and all loss, damage, cost and expense, including attorneys' fees, that may be suffered or incurred by the Railway Company, or by any person or persons, firm, association or corporation resulting from:

(a) Injury to or death of persons, loss or destruction of or damage or delay to property, including the conversion thereof, caused by, or resulting in any manner from any acts or omissions, negligent or otherwise of the Contractor, or any of the Contractor's agents, servants or employees in performing or failing to perform any of the services or duties on the part of the Contractor to be performed hereunder.

(b) The issuance of any false or fraudulent bills of lading or delivery order or the giving or receiving of any false or fraudulent receipts or delivery order for any freight or for freight charges by the Contractor, or any of the Contractor's agents or employees.

(c) Failure of the Contractor, or any of the Contractor's agents or employees, to make collections and remittances to the Railway Company as provided in this Agreement, or take up and deliver to the Railway Company order bills of lading or delivery orders as provided in Section 8, hereof, and,

(d) Theft, embezzlement or defalcation on the part of the Contractor or any of the Contractor's agents or employees.

Liability for Freight

15. The Contractor's liability for freight handled hereunder while in the possession of the Contractor shall be that of an insurer, and the records of the Railway Company as to the condition of freight when received by the Railway Company from the Contractor or when delivered by the Railway Company to the Contractor, shall be conclusive as between the parties hereto.

Defense of Lawsuits

16. To place the Contractor or the Contractor's agents, servants and employees at the service of the Railway Company, either during the term of or after the termination of this Agreement for the purpose of assisting the Railway Company in the defense of—

(a) Claims or suits for failure to comply with and obey any Federal, State or Municipal laws or ordinances or orders, rules or regulations of administrative or governmental bodies or commissions having jurisdiction,

(b) Claims or suits for loss of, damage or delay to any freight handled by the Contractor or the Contractor's agents, servants or employees, and

(c) Claims or suits for personal injury or death, arising out of or in connection with the handling or transportation of freight under this Agreement by the Contractor or the Contractor's agents, servants or employees.

Affiliation With Another Carrier

17. In the event the Contractor shall engage in, or if the Contractor or any of the Contractor's agents, servants or employees be or become associated or affiliated with any person, firm or corporation, through stock ownership or otherwise, engaging in the transportation of any freight on any highway which shall be in competition with the Railway Company in the transportation of freight by rail, or in the event the Contractor shall pick up or deliver freight for any Carrier operating on any highway in competition with rail service of Carriers, then in either event the Railway Company may, at its election, terminate this Agreement immediately by written notice.

THE RAILWAY COMPANY COVENANTS AND AGREES:

Payment to Contractor

18. To pay to the Contractor, not later than the .... day of each calendar month, in full satisfaction for the services rendered under this Agreement during the preceding calendar month, according to actual weights shown by the Railway Company's records, the following rates per 100 pounds of freight handled to or from the Railway Company's freight station.

(Compensation, such as flat rate for each delivery, rate per mile of radius from freight station or section of City with a minimum weight, weights varying within certain limits and/or maximum weight and special deliveries from suburban or outlying points may be inserted here.)

THE RAILWAY COMPANY AND THE CONTRACTOR MUTUALLY COVENANT AND AGREE:

Employees of Contractor

19. The Contractor shall employ and direct all persons required for operating vehicles and for the handling or transportation of freight under this Agreement, and such persons shall be and remain the sole employees of and subject to control and direction of the Contractor, it being the intention of the parties hereto that the Contractor shall be and remain an independent Contractor and that nothing herein contained shall be construed as inconsistent with that status. The Contractor shall conduct the work in the name of the Contractor and not display the name nor any advertisement of the Railway Company upon or about any of the Contractor's vehicles, and further covenants and agrees not to display the name or any advertising of the Railway Company in any other place or manner without having first obtained the permission and consent of the Railway Company in writing so to do.

Insurance

20. The Contractor hereby authorizes the Railway Company to procure and keep in full force and effect during the life of this Agreement:

(a) Solely for the Railway Company's protection, and not for that of the Contractor, public liability and property damage insurance for not less than .... Thousand Dollars ($..........) per person, and .... Thousand Dollars ($..........) for more than one person in any one accident, not less than .... Thousand Dollars ($..........) for property damage in any one accident, in any manner arising or growing out of operations of the Contractor hereunder.

(b) Insurance against loss, damage or delay to freight, or on account of the issuance of any false or fraudulent bills of lading, or the giving or receiving of any false or fraudulent receipt for freight related to the service herein provided for, or the giving of any false or fraudulent receipt for prepaid freight charges, or on account of the failure of the Contractor to take up and deliver to the Railway Company order bills of lading and delivery orders as provided in this Agreement.

(c) Insurance of not less than .... Hundred Dollars ($.........) per day for each vehicle operated by the Contractor in the service herein provided for, against any loss or losses which the Railway Company may incur or suffer, regardless of how caused or contributed to, by reason of the failure of Contractor to make collections and remittances under the terms of this Contract.

The insurance provided for in paragraphs (b) and (c) of this section, shall be without recourse against the Contractor except as to losses caused by the dishonesty of the Contractor or the Contractor's agents or employees, and/or the failure of the Contractor or the Contractor's agents or employees to make collections and/or to remit such collections to the Railway Company as hereinbefore provided.

The Contractor agrees to assume the expense of such insurance in an amount at the rate of .... per cent (........%) of compensation earned under this Agreement, and the Railway Company is hereby authorized to deduct such amount in remitting to the Contractor the monthly payments hereinafter provided for. If for any reason the Railway Company is unable to procure such insurance or continue the same in force for a rate not exceeding .... per cent (........%) of compensation payable to the Contractor hereunder, it shall have the right to cancel and terminate this Agreement upon .... (........) days' written notice.

The insurance hereinabove provided for is not intended to protect the Contractor from liability under any legislation enactment relating to injury or death of Contractor's officers, agents or employees and the Contractor shall at all times comply with all applicable Federal and State laws relating to Employees' Liability, Workmen's Compensation and Workmen's Insurance, or laws of a similar nature, and, when requested by the Railway Company, shall furnish proof of such compliance; and the Contractor shall indemnify and hold harmless the Railway Company from and against any and all loss, liability, damage, claims, demands, costs and expenses of whatsoever nature due to the existence of such laws or resulting from any failure by the Contractor to comply therewith.

Adjustment Claims

21. The Railway Company shall have the right, if it so elects, to adjust, settle or compromise any claim for loss or damage that may be made by a Consignee, Consignor or owner of freight transported by the Contractor hereunder and arising by reason of the failure of the Contractor to transport and deliver said freight promptly, or by reason of said freight being lost, misdelivered or damaged while in the possession of the Contractor, and all sums so paid by the Railway Company shall be held and considered as money paid for or on account of the Contractor at its request, and the Contractor shall pay such sum or sums to the Railway Company on demand.

Refunds

22. That no portion of the money paid to the Contractor for services under this Agreement shall, by any device or arrangement whatsoever, be directly or indirectly paid or refunded to any Shipper, Consignee or anyone in any way interested in the freight handled or transported under this Agreement.

Contractor Not Given Exclusive Rights

23. The Contractor shall not, by reason hereof, have exclusive right to transport said described freight, but the Railway Company shall have the right to arrange with other persons, firms or corporations for transportation of any part of its less-than-carload freight in or near the City of .... The Contractor, however, shall be entitled to transport, during the term of this Agreement, all less-than-carload freight between the Railway Company's freight station and industries where the industries express a preference for the Contractor's trucking service. In addition to performing such trucking transportation for the Railway Company of all shipments from or to industries that express a preference for the Contractor's service, the Contractor shall perform trucking transportation of such shipments as the Railway Company may elect to give to the Contractor.

Written Notices

24. Any notice herein provided to be given the Contractor by the Railway Company shall be sufficiently given and delivered if deposited in the United States mail, enclosed in an envelope, properly stamped and addressed to the Contractor at his last known place of business.

Waiver

25. It is expressly understood that no assent, expressed or implied, by either party to this Agreement, to any breach of any provision or covenant, shall constitute a precedent and shall not be deemed to be a waiver of any other provision or covenant, or of any succeeding breach of the same provision or covenant.

Assignment of Contract

26. This agreement shall inure to and bind the legal representatives, successors and assigns of the parties hereto, provided, however, that any assignment of this Agreement by the Contractor without the written consent of the Railway Company having been first obtained shall be void and of no effect.

Approval by Public Authorities

27. This Agreement is contingent upon (a) approval by such public authority as may be required by law, in a manner acceptable to the Railway Company, of the tariffs, hereinbefore referred to, and (b) the Railway Company's election to install and operate the service referred to in said tariffs and in this Agreement.

28. All titles of sections printed in boldface type are intended for convenience only, and shall not be considered a part of this Agreement nor used in any manner as an aid to the interpretation thereof.

Cancellation

29. This Agreement shall become effective from and after the .... day of ...., 193., and shall continue in effect subject to termination upon thirty (30) days' written notice from either party to the other; provided, that the Railway Company may terminate this Agreement at any time immediately upon written notice to the Contractor by reason of any adverse legislation, order or rule of any public authority or decree of court, or in the event the Contractor's services hereunder shall be unsatisfactory to the Railway Company.

IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed in ...., the day and year first above written.

WITNESS: ....Railway Company

.... By............................

WITNESS:

....Trucking Company

.... By............................

Proposed Form

FORM OF CONSTRUCTION CONTRACT

THIS CONTRACT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of .... hereinafter called the .... Company and ....
....
.... hereinafter called the Contractor.

IN WITNESS WHEREOF,

(No change in wording)

Attest:............................ ....Company.

Secretary. By..............................

Witness: ....Contractor.

By..............................

FORM OF COST—PLUS PERCENTAGE CONSTRUCTION CONTRACT

(Same as above)

FORM OF AGREEMENT FOR INTERLOCKING PLANT

THIS AGREEMENT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of .... hereinafter called the "A" Company and .... a corporation organized and existing under the laws of the State of .... hereinafter called "B" Company.

(See Note A).

Arbitration.

10. In case any question arises under this agreement or concerning the subject-matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole, disinterested arbitrator, to be selected jointly by the parties to this agreement, and if they fail to select such arbitrator within .... (........) days after demand for arbitration is made by either party hereto, then such arbitrator shall be appointed by the judge of the .... Court of ....

The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as determined by the arbitrator.

IN WITNESS WHEREOF, the parties hereto have executed this agreement in ...., the day and year first above written.

Attest:............................. ....Company.
Secretary. By...............................

Attest:............................. ....Company.
Secretary. By...............................

FORM OF AGREEMENT FOR CROSSING OF RAILWAYS AT GRADE

THIS AGREEMENT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of .... hereinafter called the "A" Company and .... a corporation organized and existing under the laws of the State of .... hereinafter called the "B" Company.

(See Note A).

Arbitration.

16. In case any question arises under this agreement or concerning the subject-matter thereof, upon which the parties hereto cannot agree, such question shall be settled by a sole, disinterested arbitrator, to be selected jointly by the parties to this agreement, and if they fail to select such arbitrator within .... (..........) days after demand for arbitration is made by either party hereto, then such arbitrator shall be appointed by a judge of the .... Court of ....

The expense of arbitration shall be apportioned between the parties hereto, or wholly borne by either party, as determined by the arbitrator.

IN WITNESS WHEREOF, the parties hereto have executed this agreement in ...., the day and year first above written.

Attest:............................. ....Company.
Secretary. By...............................

Attest:............................. ....Company.
Secretary. By...............................

FORM OF LEASE FOR INDUSTRIAL SITE

Parties.

1. THIS LEASE, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of .... hereinafter called the .... Company and .... hereinafter called the Lessee.

IN WITNESS WHEREOF, the parties hereto have executed this lease in .... the day and year first above written.

Witness:............................ ....Company.
By..............................

Witness:............................ ....Lessee.
By..............................

FORM OF AGREEMENT FOR INDUSTRY TRACK

THIS AGREEMENT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of .... hereinafter called the Railway Company and .... hereinafter called the Industry.

IN WITNESS WHEREOF,

(No change)

Witness:............................ ....Company.
By..............................

Witness:............................ ....Industry.
By..............................

FORM OF AGREEMENT FOR TRACKAGE RIGHTS

(See Note B)

Arbitration.

23. Same proposed reading as proposed in Form of Agreement for Interlocking Plant.

Execution.

26. IN WITNESS WHEREOF, the parties hereto have executed this agreement in ...., the day and year first above written.

Attest:.............................. ....Company.
Secretary. By..............................

Attest:.............................. ....Company.
Secretary. By..............................

FORM OF LICENSE FOR WIRES, PIPES, CONDUITS, DRAINS, HOPPER PITS, AND OTHER STRUCTURES ON RAILWAY PROPERTY

THIS AGREEMENT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of .... hereinafter called the Railway Company and .... hereinafter called the Licensee.

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

Witness:.......................... ....Company.
By..............................

Witness:.......................... ....Licensee.
By..............................

FORM OF AGREEMENT FOR PLACING SNOW OR SAND FENCES OFF THE RAILWAY COMPANY'S PROPERTY

THIS AGREEMENT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of .... hereinafter called the Railway Company and .... hereinafter called the Licensor.

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

Witness:.......................... ....Company.
By..............................

Witness:.......................... ....Licensor.
By..............................

FORM OF AGREEMENT FOR JOINT USE OF PASSENGER STATION FACILITIES

Arbitration.

12. Same proposed reading as proposed in Form of Agreement for Interlocking Plant.

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

Attest:............................ ....Company.
Secretary. By..............................

Attest:............................ ....Company.
Secretary. By..............................

FORM OF AGREEMENT FOR JOINT USE OF FREIGHT TERMINAL FACILITIES

THIS AGREEMENT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of .... hereinafter called the "A" Company; and ...., a corporation organized and existing under the laws of the State of .... hereinafter called the "B" Company.

Arbitration.

14. Same proposed reading as proposed in Form of Agreement for Interlocking Plant.

IN WITNESS WHEREOF, the parties hereto have executed this agreement in ...., the day and year first above written.

Attest:............................ ....Company.
Secretary. By..............................

Attest:............................ ....Company.
Secretary. By..............................

FORM OF LICENSE FOR PRIVATE ROAD CROSSING

THIS AGREEMENT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company and ...., hereinafter called the Licensee:

The Railway Company grants unto the Licensee the license and privilege of constructing, maintaining and using ....
(here insert character of structure whether grade, over or under)

....
the lands and right-of-way and .... the tracks of the Railway Company situated in .... and substantially as shown on the plan hereto attached, designated as .... and dated .... and made a part hereof:

IN WITNESS WHEREOF, the parties hereto, have executed this agreement in ...., the day and year first above written.

Witness:.......................... ....Company.
By..............................

Witness:.......................... ....Licensee.
By..............................

FORM OF AGREEMENT FOR PURCHASE OF ELECTRICAL ENERGY FOR OTHER THAN TRACTION PURPOSES

(Arbitration clause to be changed to conform with that of Interlocking Plant.)

IN WITNESS WHEREOF, the parties hereto have executed this agreement in ...., the day and year first above written.

Witness:.......................... ....Company.
By..............................

Witness:.......................... ....Company.
By..............................

FORM OF AGREEMENT FOR PURCHASE OF ELECTRICAL ENERGY FOR TRACTION AND OTHER PURPOSES

In Witness Whereof, the parties hereto, have executed this agreement in ...., the day and year first above written.

Attest:............................ ....Company.
Secretary. By..............................

Attest:............................ ....Company.
Secretary. By..............................

FORM OF AGREEMENT FOR JOINT USE OF POLES ON RAILWAY LANDS

(Note: To be omitted)

THIS AGREEMENT, made this .... day of .... 19..., by and between .... Company, a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company and .... Company, a corporation organized and existing under the laws of the State of ...., hereinafter called the Wire Company.

(Arbitration clause to conform to clause in Form for Interlocking Plant.)

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

Attest:............................ ....Company.
Secretary. By..............................

Attest:............................ ....Company.
Secretary. By..............................

FORM OF AGREEMENT FOR FURNISHING WATER FROM RAILWAY WATER SYSTEMS TO EMPLOYEES AND OTHERS

THIS AGREEMENT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company, and ...., hereinafter called the Consumer.

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

Witness:.......................... ....Company.

By..............................

Witness:.......................... ....Consumer.

By..............................

FORM OF AGREEMENT FOR PURCHASE OF WATER

THIS AGREEMENT, made this .... day of .... 19...,
by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company, and ....
hereinafter called the Water Company.

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

Attest:............................ ....Company.
Secretary. By..............................

Attest:............................ ....Company.
Secretary. By..............................

FORM OF AGREEMENT FOR THE ORGANIZATION AND OPERATION OF A JOINT PASSENGER TERMINAL PROJECT

(Both Parts)

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

FORM OF AGREEMENT FOR THE USE OF RAILWAY PROPERTY BY HIGH PRESSURE PIPE LINES WITH SPECIAL REFERENCE TO PIPE LINES CARRYING INFLAMMABLE OILS AND GAS

THIS AGREEMENT, made this .... day of .... 19...,
by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company, and ....
................, hereinafter called the Licensee.

(No change in wording)

Attest:............................ ....Company.
Secretary. By..............................

Witness: ....Licensee.
.... By..............................

FORM OF CONVEYANCE OF TITLE GRANTING THE RIGHT TO CONSTRUCT AND MAINTAIN BUILDINGS OVER RAILWAY PROPERTY

(No change)

FORM OF AGREEMENT FOR WIRE LINE CROSSINGS

THIS AGREEMENT, made this .... day of .... 19..., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company and ...., hereinafter called the Lessee.

In Witness Whereof, the parties hereto have executed this agreement in .... , the day and year first above written.

Witness:.......................... ....Company.

By...............................

Witness:.......................... ....Lessee.

EXPLANATORY NOTES

Note A

Form for Interlocking Plant

It is suggested that the parties be named the "A" Company and the "B" Company in the appropriate blank spaces and thereby be similar to the Passenger Station Form.

Form for Railway Crossing at Grade

(Same as above)

Note B

Form for Trackage Rights

It is suggested the "A" Company be substituted for Grantor and the "B" Company for Grantee in the appropriate blank spaces and the small typed words between the lines be eliminated. This will then be similar to three other forms where A and B is used to designate the Railway Companies.

The Note under the title would also be eliminated.

The "Arbitration" clause should be similar to the phraseology shown under "Form of Agreement for Interlocking Plant."

Use of Sideheadings in Various Forms

It is recommended that in the body of the various forms, appropriate sideheadings be used and placed above the particular paragraph to which they relate. The introduction of these sideheadings does not involve any change in the respective forms. The Secretary's office has been furnished with a list of sideheadings for the forms involved.

REPORT OF SPECIAL COMMITTEE—ECONOMICS OF BRIDGES AND TRESTLES

ARTHUR RIDGWAY, *Chairman;*
E. A. CRAFT,
F. H. CRAMER,
R. P. HART,
A. C. IRWIN,
A. N. LAIRD,
H. S. LOEFFLER,
F. J. PITCHER,
T. H. STRATE,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subject:

> Comparative economic value of steel, treated timber, and concrete in bridges, trestles, and viaducts under various conditions of service, with due consideration of relative influence of durability of materials and obsolescence of property.

During the past year the Committee has continued an intensive study of the assigned subject. A consideration of the meager data received together with the work on a similar subject inherited from the Committee on Wooden Bridges and Trestles very definitely indicates that the matter of relative economy demands unusual and exhaustive treatment. Progress is being made, and the Committee requests the subject be continued.

SPECIAL COMMITTEE ON ECONOMICS OF BRIDGES AND TRESTLES,
ARTHUR RIDGWAY, *Chairman.*

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REPORT OF SPECIAL COMMITTEE ON STRESSES IN TRACK

Arthur N. Talbot, *Chairman;*
C. B. Bronson,
John Brunner,
W. J. Burton,
W. C. Cushing,
Robert Faries,
C. W. Gennett,
H. E. Hale,
J. B. Jenkins,
Geo. W. Kittredge,
P. M. LaBach,
C. G. E. Larsson,
John V. Neubert,
J. de N. Macomb,
G. J. Ray,
W. M. Dawley, *Vice-Chairman;*
Albert Reichmann,
H. R. Safford,
Earl Stimson,
F. E. Turneaure,
J. E. Willoughby,
Committee.

To the American Railway Engineering Association:

The Special Committee on Stresses in Railroad Track, cooperating with the Committee of the American Society of Civil Engineers and with the Association of American Railroads, presents the following report of progress:

During the past year the staff has continued to carry on investigations relating to railroad track. The work has included study and tests on a number of matters.

The action of rail-joints in track has continued to receive attention, particularly to learn the source of wear and the advantages and needs of building up joint bars by a welding process. Laboratory tests have also been made along the same lines. The study of rail-joints and of methods of design and ways of judging of the merits of the section of a joint bar has been continued. The study of certain patent claims and their relation to the design of joint bars like angle bars for the lighter rail sections has also been continued. A study has been made of the elements entering into tie-plate design and information relating to this has been furnished to the Committee on Track.

The Committee has been given the use of certain extensive experimental data of two railroads (the Pennsylvania and the Erie). A study of the results is now being made, with plans to analyze, discuss and draw conclusions from some parts of this material, which it is expected will throw light on certain effects of the rolling stock on the track itself. For a part of the tests the records include measurements of the vertical and lateral forces acting on the rails due to the movement of locomotives and the forces applied by reason of counterbalance and of various lateral and vertical movements of the equipment, as well as to conditions in the track.

Recently the test party has made tests on three long stretches of welded rail on the Delaware and Hudson Railroad (one of the stretches being nearly a mile and another nearly a mile and a quarter in length). The purpose of these tests is to learn what anchorage is given by the ties and ballast at the ends of the stretches and along its length to resist the forces set up by changes in the temperature of the rail, and to learn how the influences tending to change the length and alinement are met by the track, and to aid in finding whether other steps need be taken to resist these forces and other forces developed by the temperature changes. The plan is to repeat the measurements and observations at low temperatures in the winter and also at high temperatures in the summer. Even the changes found in the tests from the lower temperatures of early morning to the warmer temperatures of afternoon gave pertinent information on the daily development of stress and anchorage along a stretch of track and suggests some of the variable and the local conditions that enter into the phenomena. It is evident that information on the conditions involved in such track is essential in judging the eventual success of this rather bold advance in practice.

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Other matters on the program include a study of superelevations and easements of curves for high-speed trains. As a beginning analytical studies have been made with respect to centers of gravity, length between trucks, springs, connections between wheels and frames and bodies, and other conditions of the rolling stock.

It is planned to continue the work the coming year along the lines of the general program. Much remains to be done in the investigation of the rail-joint, especially in reference to its wear and maintenance in track. Information is needed on the relation between the actual condition of the rolling stock and the track itself. It is apparent that certain elements of track action have not been sufficiently investigated. There are needs connected with the use of increased speed for both passenger and freight trains. Attention should be called to the fact that the subject of locomotive counterbalance, which has been assigned to the Committee for several years, and many other related matters on the influence of the design and operation of rolling stock (as was outlined in a report of the joint conference committee on "A Proposed Investigation of the Interrelation of Rolling Stock and Track" referred to in the report of this Committee a year ago) cannot be taken up in any adequate manner without much larger facilities and funds than are yet available. A further important project is the preparation of a general resumé of the results of the work of the Committee and a summary of its findings—itself an undertaking that will consume considerable time.

As related to the topic of superelevations and easements of curves, reference may be made to the discussion given by the Chairman at the last Annual Meeting, which may be found on page 969 of Volume 36.

THE SPECIAL COMMITTEE ON STRESSES IN RAILROAD TRACK,
A. N. TALBOT, *Chairman.*

REPORT OF COMMITTEE XVI—ECONOMICS OF RAILWAY LOCATION

F. R. Layng, *Chairman;*
S. E. Armstrong,
F. A. Barnes,
J. L. Campbell,
H. H. Edgerton,
R. P. Forsberg,
E. A. Humphreys,
E. E. Kimball,
E. E. King,
Fred Lavis,
Wm. Michel,
G. H. N. Monkman,
F. A. Russell,
H. C. Searls,
H. B. Shattuck,
H. M. Shepard,
A. W. Galbreath, *Vice-Chairman;*
C. B. Stanton,
R. S. Stephens,
H. M. Stout,
J. E. Teal,
H. M. Tremaine,
W. D. Wiggins,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents its report on the following subjects:

(3) Compile operating data essential to establish units for making line and grade revisions to meet operating requirements. It is recommended that the report be received as information (Appendix A).

(4) Effect of speeds in excess of 75 miles per hour on the economics of railway location, collaborating with Committee XXI—Economics of Railway Operation and the Special Committee on Complete Roadway and Track Structure. It is recommended that the report be received as information and progress (Appendix B).

Progress is reported on (1) Revision of Manual; (2) Review reports heretofore made on the economics of grade revision as affected by electric operation, collaborating with Electrical Section.

The Committee on Economics of Railway Location,
F. R. Layng, *Chairman.*

Appendix A

(3) OPERATING DATA ESSENTIAL TO ESTABLISH UNITS FOR MAKING LINE AND GRADE REVISIONS TO MEET OPERATING REQUIREMENTS

W. D. Wiggins, Chairman, Sub-Committee; E. E. King, Fred Lavis, F. A. Russell, C. B. Stanton, R. S. Stephens, J. E. Teal.

Definitions

"Operating data" embraces such available facts and formulae, based on experience, tests, and recorded statistics, as may be useful in determining, or indicating the best methods for determining, units of service and unit costs.

Units for making studies of line and grade revisions are:

(1) Units of freight traffic carried over a line under consideration or some part of such line, expressed in tons and ton-miles (net and gross), cars and car miles, in each direction, loaded and empty, and classified with respect to the character of train service required to move each class; and units of passenger traffic expressed in cars and trains and the weight in tons thereof.

(2) Units of service required to move a given number of units of traffic over a line under consideration. These units for road service are trains, train-hours, and train-

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miles; and locomotives, locomotive-hours and locomotive miles for each class of service in each direction.

(3) Units of labor, fuel and material applicable to units of service, and to maintenance and operations of all facilities required to render service in addition to units of service listed in item (2).

(4) Unit costs applicable to units of service and/or to units of labor, fuel and material.

Preliminary Studies

The preliminary studies and conclusions that must precede the making of studies of proposed line and grade revisions are as follows:

(1) That the traffic of the line is permanent or at least will continue for such number of years that economies in operation will exceed the cost of revision plus interest.

(2) That the traffic, or a substantial part of it, may not be diverted to a more economical existing route as a result of acquisition of other lines or consolidations.

(3) That there are no preferable alternatives, such as:

(a) Substitution of modern or heavier motive power
(b) Installation of signals or improved train dispatching methods
(c) Extension of or additional main tracks or sidings
(d) Improvement of track and bridges to increase speed or permit the use of heavier motive power
(e) Enlargement of terminals
(f) Changes in operating methods
(g) Any combination of the foregoing or other changes in the physical condition or operating practices
(h) Electrification of the line.

After these preliminary studies have been completed, the conditions accurately appraised, and two or more line and grade revisions outlined, the problem is to find the relative economic values of the alternate plans.

Freight Traffic Units

The basic traffic unit is the ton (net and gross), taking into consideration distance, direction of movement and speed required. Speed requirements vary for different commodities.

Any traffic survey must be made from original records of the operating division under consideration. The data should be obtained preferably from the conductor's wheel reports, for a period long enough to be representative, in order that net tons, gross tons, and number of loaded and empty cars may be found for each class of trains. Where important movements leave or enter the operating division at intermediate points, analysis of such movements and their effect upon the service units of the operating division as a whole may be the most important step in the whole study.

The composition of trains by classes, i.e., number of loaded and empty cars; ratio of tare weight to gross weight; relation of total empty car movement to loaded car movement; number of cars in a full tonnage train; is of great importance in determining the number of service units.

Service Units

The service units of an existing operating division are developed from the division records, in the same manner as traffic units. For road service they include for each direction and each class of service:

Freight train service (a) slow freight, (b) fast freight, and (c) local freight:

(1) Trains, number
(2) Train-miles
(3) Train-hours
(4) Locomotives, number of each type and size operated over the division.
    (a) Principal (b) Helper, (c) Light.
(5) Locomotive-miles for (a), (b) and (c) in item 4.
(6) Locomotive-hours for (a), (b) and (c) in item 4.

Calculations to determine the location of ruling grade should be made separately for the tonnage in each class of freight train service and finally for the tonnage of all classes together, and if the latter finds the limiting grade at a different location than for slow freight or fast freight separately, it will be necessary to determine which of these services controls the total tractive power operated over the division.

It is not safe to assume that the number of service units actually employed on an existing line is the least number consistent with limiting grades and other physical limitations. Therefore the following test should be made:

(1) Compare the actual average train load with the capacity of the average locomotive. Find by analysis and further investigation the reason for the difference. This investigation will show either (a) that the service units may be reduced before making comparison with a proposed new line, or (b) that there are limitations other than grades that may similarly affect the number of service units of the proposed new line.

(2) Determine the speed in miles per hour by dividing train-miles by train-hours for each class of service. Tabulate delays with respect to causes and also with respect to the places where they occur and reach definite conclusions as to the underlying causes. This investigation will show either (a) that the train speed on the existing line may be increased before making comparison with the proposed new line, or (b) that conditions exist which may affect the train speed over the proposed new line.

(3) Investigate the following data for locomotives in service, age, average tractive power, coal and water capacity, modern appliances and engine failures.

(4) Investigate the following items as to their effect on train speed:

(a) Condition of track and bridges
(b) Adequacy of main and running tracks and sidings
(c) Location and adequacy of coal and water stations
(d) Suitability and conditions of train dispatching facilities
(e) Adequacy and efficiency of fixed signals
(f) Interference at intermediate yards
(g) Operating practices with respect to picking up and setting off cars or filling out or reducing at intermediate points
(h) Efficiency of operating methods and personnel.

Completion of these studies will probably show that changes in physical conditions other than revision of line and grade are practical at reasonable expense and would reduce the number of service units in present operation. If so, the statement of present service units which is to be the basis of further calculations should be appropriately modified so that the comparisons finally developed will be an accurate measure of the difference in service units flowing from the change to be made in the line and grade.

Service Units on the Proposed Line

After developing the particular kind of locomotive to be employed in each class of service, estimate the service units required to move the pre-determined volume of traffic over the proposed line. If the locomotives to be used are not the same as those used on the existing line, the service units on the existing line will have to be modified to show the effect of using on the existing line the locomotives that are to be used on the proposed line.

(I) TRAIN LOAD

The practical train load in each class of service on the proposed line will be determined by giving consideration to:

(a) Capacity of the locomotive
(b) Train loads actually hauled over similar lines, especially where dynamometer tests have been made
(c) Train loads actually hauled over the existing line in relation to locomotive capacity
(d) Service requirements, e.g., number of fixed schedules required to protect deliveries and connections regardless of the tonnage available at the time of departure
(e) Fluctuations in traffic volume, weather, physical and operating conditions which will reduce the annual average train load below the maximum attainable under favorable conditions.

(II) TRAIN SPEED

The time of movement for each class of service in each direction over the proposed line will be estimated by a study of past performance under similar physical, operating and traffic conditions. Average train miles per train hour and train-hours per trip in each direction and class of service must be determined in order to compute service units for the proposed line. In calculations of speed the following data should be considered:

(a) Analysis of the location and causes of delay on the existing line, particularly any part of which will form without change a part of the proposed line.
(b) Actual performance of trains on any other existing line where the conditions are similar to those of the proposed line.
(c) If the number of trains will be reduced, it will be helpful to prepare time and distance charts of proposed movements for an average day and for a maximum day.

(III) COMPUTATION OF SERVICE UNITS

Train load and train speed having been determined, the service units required for the pre-determined volume of traffic may be computed. Comparison of the service units of the two lines will then show the number of train miles, train hours, locomotive miles and locomotive hours that will be saved by the proposed line and grade revision.

Costs

After the saving in service units is determined it is necessary to assign a money value to the service units. Values must also be assigned to saving in maintenance and operations of the facilities, in addition to the service units, required to render service.

Cost Data

These data are of two general classes:

(1) That which may be developed from accounting records
(2) That which has been or may be developed from special studies in particular cases.

From accounting records average unit costs may be developed for every Class I railroad as a whole. Expenses are separated as between freight, passenger and yard services, such separation of common items being on an arbitrary basis.

Average freight unit costs developed from the accounting records merely reflect the average for all the different freight service on all lines covered by the report. Operating conditions for the line under consideration are rarely comparable with those of the entire system for which the average costs may be developed from accounting records. Consequently it is nearly always necessary to develop such data by special studies.

Cost Items

The following items, although they do not include all expenses, will amount to approximately 80 per cent of the total and any comparisons made on same will be sufficiently accurate to be used for the basis of decisions:

Enginemen—Wages
Trainmen—Wages
Enginehouse Expenses
Fuel
Water
Lubricants
Other Supplies
Locomotive Repairs
Car Repairs (Per Diem)
Maintenance of Way and Structures
Interest
Depreciation
Insurance
Taxes

(1) Wages

It is not difficult to ascertain the actual amount of wages for the existing line and the estimated wages for the proposed line after train loads and train speeds are determined. Care must be exercised in both cases to include all incidental payments such as dead heading, light movements, held away from home terminal and all allowances provided for in wage schedules.

(2) Enginehouse Expenses

The number of locomotives turned is a better measure of enginehouse expenses than either miles or hours of service because the amount of work done in wiping, cleaning, dispatching, dumping ashes, washing boilers, cleaning fireboxes, checking equipment, cleaning ash and cinder pits, operating turntables, inspecting smokestacks and ashpans and hostling will be closely proportionate to the number of engines turned (if uniform in size). The number of men of each occupation required to perform the work depends upon the time within which each operation must be completed or the number of engines that must be dispatched within a given time.

In cases where a grade revision will reduce the number of engines turned the expenses should be analyzed and classified so as to separate those items which will be affected in proportion to the decrease and those which will not be.

(3) Fuel

The cost of fuel for operating a line under consideration will depend primarily upon:

(a) Quantity of fuel consumed
(b) Price at the mines
(c) Foreign line freight charges (if any)
(d) Cost of transportation and handling on the line of the consuming carrier.

The quantity of fuel required to move a given amount of traffic on the line under consideration depends upon:

(a) Number of service units required, tractive power considered
(b) Number of locomotives in service on the line
(c) Relation to total service-time of time; (1) working at full capacity; (2) working at less than full capacity; (3) drifting; (4) standing at intermediate points; and (5) standing at terminals
(d) Steaming efficiency or relative utilization of heat units consumed
(e) Firing efficiency
(f) Quality of fuel.

The number of locomotives in service (assigned or held under steam) and consuming fuel during non-productive time, as well as the amount of power actually required to move the load, will affect the quantity of fuel consumed.

Disregarding variation in steaming efficiency, the amount of fuel consumed will be proportionate to the horsepower developed. Horsepower-hours being a combination of load, distance and speed, all three must be considered in determining the horsepower-hours required. If conditions permit the train load will be such as to utilize maximum drawbar pull on the ruling grades and maximum horsepower on level sections. The speed will vary from the practicable minimum on ruling grades to the safe or economical maximum on level sections. These minima and maxima may be such as to preclude obtaining maximum drawbar pull and/or maximum horsepower.

To determine the effect of a grade revision on fuel consumption it is therefore necessary to compute horsepower-hours for a round trip, on the present line and for the proposed line, and apply the average fuel consumption per horsepower-hour.

The fuel consumption per horsepower-hour must be obtained from the results of actual tests, made with fuel and locomotives similar to those to be used on the line under consideration and under operating conditions and grade similar to the line considered.

(4) Water, Lubricants and Other Supplies

These items are a very small part of the total cost. Results obtained from the use of statistical unit costs will be sufficiently accurate.

(5) Locomotive Repairs

It is apparent from consideration of the functions of a locomotive that: (1) Tires, journals, bearings, valves and other moving parts of the machinery will wear out in almost direct proportion to distance traveled. Curvature is also an important factor which affects wear and tear of the running gear of locomotives.

(2) Firebox, flues, boiler, and other parts of the power plant and all the tender except wheels and journals will deteriorate with time rather than distance.

(3) Other parts not mentioned in (1) and (2) may be affected by both time and distance.

It is also clear that where the relationship between time and distance is constant on two different lines either unit cost (per mile or per hour) will get the same results. Speed, in miles per hour, while running is not so important in this respect as the mileage in relation to total working and standing time as measured by the miles run per serviceable day. Where the miles per serviceable locomotive per day and the average tractive power are the same for a proposed line as for an existing line where the unit costs are known, such unit cost may be applied to the service units of the proposed line (either miles or hours) provided the unit costs are for a representative period.

If the mileage per serviceable locomotive per day will be greater on the proposed line than on the line for which unit costs are known, the cost per locomotive mile will probably be less and the cost per locomotive hour greater.

(6) Car Repairs

The use of 60 per cent of the standard per diem charge in figuring cost of car repairs for different lines is sufficiently accurate to determine any savings due to line and grade revisions.

(7) Maintenance of Way and Structures

Special studies must be made in order to determine cost of Maintenance of Way and Structures for the existing line and for other existing lines having same line grade and subgrade conditions as proposed line and handling same volume and class of traffic. The units of labor and material used in maintenance can be obtained from the records of the carrier.

(8) Interest and Depreciation

Interest should be figured on the actual cash outlay chargeable to operating expenses as well as capital account and no credit should be deducted for property retired except the salvage therefrom.

If locomotives are released due to grade revision and can be used elsewhere and the purchase of additional locomotives to that extent ultimately avoided, there will be an actual saving in interest and depreciation.

Conclusion

It is recommended that this report be accepted as information and the subject continued.

Appendix B

(4) EFFECT OF SPEEDS IN EXCESS OF 75 MILES PER HOUR ON THE ECONOMICS OF RAILWAY LOCATION

R. P. Forsberg, Chairman, Sub-Committee; F. A. Barnes, H. H. Edgerton, E. A. Humphreys, Wm. Michel, H. M. Stout, W. D. Wiggins.

Introduction

High speed passenger trains have caught the popular fancy and have of late received great publicity in our daily press and magazines. Although there are many interesting installations in service, some using standard steam, electric, or internal combustion motive power, and designs are under way of light weight equipment with high strength materials, internal combustion motive power, with radical changes in equipment outlines, there has been very little, if any, published analysis of the motive power requirements and economies involved in running trains at speeds in excess of 75 miles per hour.

While the benefits of high speed passenger trains, in bringing back to the railroads some of the passenger business lost to other transportation agencies is admitted, it must be remembered that a railroad profile does not consist of level grades, that the alinement is not all tangent and that both freight and passenger traffic is handled on the same tracks. As speed increases it becomes more difficult to make the compromise as to elevation of the outer rail on curves to accommodate these higher speeds and the slower movements.

The profile is really a series of upgrades and downgrades and over that portion of the profile which is downgrade, some trains are now operating at the maximum permissible speed, the maximum speed being generally limited by alinement. On the upgrades, the effective grade is of importance as power must be provided to handle the trains at about the same speeds as on downgrades, if the same schedules are to be maintained.

The alinement is a series of tangents and curves of varying degrees of curvature. On that portion of the alinement which is tangent and level, trains are operated at the speed which will develop the maximum horsepower of the locomotives. On the curves the degree of curvature is important as it limits the safe speed at which trains can operate.

Freight traffic requirements do not demand speeds in excess of 75 miles per hour and the benefits from improvements in grade and alinement necessary to obtain speeds in excess of 75 miles per hour for passenger service may not be of great economic value, and it is possible that improvements in alinement may result in almost negligible economies in freight service.

Maximum Speed and Average Speed

The fastest trains today have an average speed between 70 per cent and 80 per cent of the rated maximum. The average train schedule speed scarcely exceeds 60 per cent of the maximum. This low average speed is due to restrictions which require slowdowns and to stops. The elimination of such slowdowns and stops as can be avoided is an economical method of increasing average train speeds. Material increases in average speed have been accomplished on several roads by the elimination of slowdowns and stops and this feature should be thoroughly investigated before making expenditures for grade and curvature revisions or for the purchase of new equipment. It may be found that average speeds can be increased to that desired, without grade or curvature revision, or change in equipment.

Items Affecting Speed

The principal items of railway location affecting speed are:

(1) Grades
(2) Curvature

In addition to the items of location, the following items of roadway, track and structures affect maximum and average speeds:

(1) Condition of roadbed
(2) Track construction and standard of maintenance
(3) Location of signals
(4) Length and location of passing sidings

Grades

As a broad statement it may be said that the lighter the grade the greater the speed with no increase in tonnage, or in other words, a train of any tonnage can run faster on a light grade than it can on a heavy one, and that the economies from grade reduction, permitting higher speed with same tonnage are largest when the percentage of ruling grade mileage to total mileage is smallest.

Curvature

In the past engineers in establishing the profile and alinement of a railroad, considered grades as a most important factor, and did not give as much consideration to alinement, as now becomes necessary.

However, as higher speeds become desirable, or are required, the item of curvature becomes more important and in the future this feature of location will demand more consideration.

Curvature is perhaps the most important item limiting the maximum speed of a locomotive in locations where the speed is not limited by grades.

Maximum speed is not only limited on curvature to the permissible safe speed, but the average speed is further reduced due to slowing down in approaching the curves and the time required to accelerate to maximum after leaving the curve. On alinements where the tangents are short it is often impossible to accelerate to the maximum speed before it is necessary to reduce speed again for curvature.

The design of the internal combustion motive power and light weight cars makes possible higher speeds on curves of the same degree when such equipment is substituted for steam power and ordinary coaches due to the lower center of gravity of the new equipment. This introduces another factor in any study of curve reduction. The adverse effect of the lower center of gravity on the track structure must also be considered.

In operating at speeds in excess of 75 miles per hour, it will also be necessary to provide longer and more gradual easement curves at the junction of curves and tangents in order to provide easy riding at such speeds. In case this is not done the benefits derived from faster passenger schedules may be lost due to the discomfort to passengers.

Roadbed and Track

Any irregularities in line and surface of the track are more pronounced as speed increases. The impact caused by such irregularities increases rapidly with speed. The high speeds under discussion demand the highest standards of track construction and maintenance.

Location of Signals

On some of the roads where maximum speed of passenger trains has been materially increased, it has been found necessary to change the location of signals. Signal location involves the question of braking distances. With different maximum speeds for freight and passenger service the location of signals to produce the most economical operation will demand considerable study.

Location of Passing Sidings

The elimination of delays is vital if average speed is to be increased and economical operation is to be obtained. This may require the relocation of present sidings and the installation of additional sidings.

Economic Justification of High Speeds

The foregoing shows that many expenditures may be necessary to obtain speeds in excess of 75 miles per hour. It is imperative that all such expenditures be included in any study of costs, together with the net effect of such service on transportation expenses.

At present there is a lack of definite data showing equipment repair costs for internal combustion motive power operated at speeds in excess of 75 miles per hour due to the short time such equipment has been in service.

The necessary changes in grade, alinement, and roadway and track structure will depend upon the individual characteristics of the section of road on which trains are operated at speeds in excess of 75 miles per hour.

Conclusion

It is recommended that this report be accepted as information and the subject continued.

REPORT OF COMMITTEE I—ROADWAY

Geo. S. Fanning, *Chairman;*
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J. B. Akers,
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E. J. Bayer,
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A. E. Botts, *Vice-Chairman;*
C. S. Robinson,
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P. T. Simons,
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H. M. Swope,
J. B. Trenholm,
O. H. Wainscott,
A. W. White,
F. E. Wiesner,
W. H. Woodbury,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the subjects assigned. Under each general subject we were directed to include in the study:

(a) Revision of Manual.
See Appendix C—Deletion of "Definitions" and material on "Waterways".
" " E—Deletion of Specifications for Cast Iron Culvert Pipe.
" " F—Revised Specifications for Corrugated Metal Culvert Pipe.
" " G—Revised Specifications for Formation of the Roadway.
" " I—Deletion of material on "Tunnels".
" " J—Deletion of material on "Signs".

(b) Adherence to recommended practice.

(c) Progress in the science and art.

(d) Outline of Work (Appendix A).

The subjects assigned are as follows:

1. Physical properties of earth materials, particularly
   Bearing power (Appendix B). Progress report.

2. Natural waterways, particularly
   Drainage areas, water runoff and size of openings (Appendix C). Progress report, with recommended deletions from Manual.

3. Culverts, particularly
   Service life of culverts (Appendix D). Complete and presented as information.
   Specifications for cast iron culvert pipe (Appendix E). Progress report, with recommended deletions from the Manual.
   Specifications for corrugated metal culvert pipe (Appendix F). Complete. Recommended for publication in the Manual.

4. Formation of the roadway, particularly
   Specifications (Appendix G). Complete. Recommended for publication in the Manual.

5. Roadway drainage, particularly
   Soft spots and water pockets (Appendix H). Complete and presented as information.

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* Died September 25, 1935.

Bulletin 381, November, 1935.

6. Roadway protection, particularly
   Permanent roadbed. Progress in study—no report.

7. Tunnels, particularly
   Construction (Appendix I). Complete, with recommended deletions from the Manual.

8. Fences, particularly
   Corrosion-resisting fence wire, collaborating with appropriate sub-committees of Committee A–5 on Corrosion of Iron and Steel, A.S.T.M. Progress in study—no report.

9. Signs (Appendix J). Progress report, with deletions from Manual.

The Committee on Roadway,
Geo. S. Fanning, *Chairman.*

Appendix A

OUTLINE OF WORK

Each sub-division prepared by the Sub-Committee in charge of the general subject.

1. Physical Properties of Earth Materials

A. General. Scope. Importance.

B. Definitions. Soil terms; map, texture, structure consistence, compactness, cementation.

C. Physics of Soils.
   - a. Soil genesis.
   - b. Physical properties. Internal friction. Cohesion. Compressibility. Elasticity. Permeability. Capillarity.
   - c. Classification of soils. Mechanical analysis. Engineering properties. Uniform subgrade groups.

D. Roadbed.
   - a. Behavior. Moisture effects. Consolidation. Lateral flow. Frost action.
   - b. Load capacity. Relation to ballast. Allowable pressures.
   - c. Construction.
   - d. Maintenance.
   - e. Other subgrade problems. Roads.

E. Roadway Cuts.
   - a. Earth cuts. Moisture effects. Slides. Slopes.
   - b. Rock cuts. Moisture effects. Slides. Rock-falls. Slopes.

F. Embankments.
   - a. Behavior. Moisture effects. Shrinkage. Swell. Subsidence; marshes, bog holes. Slides.
   - b. Effect of method used in placing fill.
   - c. Width of embankment.
   - d. Slopes.

G. Structural Foundation Soils.
   - a. Settlement. Moisture effects. Consolidation. Lateral flow.
   - b. Bearing capacity. Area effects. Footing foundations. Slab foundations. Piling foundations.
   - c. Settlement records.

H. Foundations for Retaining Structures.
    a. Stability of structure. Moisture effects.
    b. Requirements. Retaining walls. Dams and reservoirs.

I. Tests.
    a. Field. Borings. Loading tests.
    b. Laboratory.

2. Natural Waterways.

A. General. Scope. Importance.

B. Definitions.

C. Drainage Areas and Water Run-off.
    a. Field surveys.
    b. U.S. weather report data.

D. Size of Waterway Openings.
    a. Formulae. Data on past performance.
    b. Effect of adjacent structures.

E. Prevention of Erosion.
    a. Channel protection. Plantings. Rip-rap; mattresses. Drift catchers. Channel relocations. Diversion levees. Retards; jetties. Reduction of gradients; check dams. Increase of gradients; flumes.

F. Protection Against Floods and Washouts.
    a. Roadway; overflow, side wash, wave action, percolation. Rip-rap. Sand bags. Anchoring. Slope paving.
    b. Bridges; scour, undermining, drift, ice. Rip-rap. Sand bags. Anchoring. Flumes; jetties. Gravel and debris racks.

3. Culverts

A. Definitions.

B. Location and Type of Opening.
    a. Waterway required.
    b. Span required.
    c. Character of hydraulic traffic (abrasive, corrosive, etc.)
    d. Topographic conditions determining angle, gradient and length of structure.
    e. Foundation conditions.
    f. Height and character of embankment.
    g. Loading, live and dead.
    h. Economics of various types. Service life. First cost. Annual cost (interest, depreciation, and maintenance).

C. Vitrified Clay Pipe Culverts.
    a. Specifications.
    b. Grades for special conditions.
    c. Installation. Open trench. Tunneling.

D. Cast Iron Pipe Culverts.
    a. Design and specifications.
    b. Grades for special conditions.
    c. Installation. Open trench. Tunneling. Jacking.

E. Concrete Pipe Culverts.
    a. Design and specifications. Masonry Committee.
    b. Types for special conditions.
    c. Installation. Open trench. Tunneling. Jacking.

F. Corrugated Metal Culverts.
  a. Design and specifications.
  b. Types for special conditions.
  c. Installation. Open trench. Tunneling. Jacking.

G. Box Culverts. Design, Specifications, Construction.
  a. Timber.
  (b. Stone. Masonry Committee).
  (c. Concrete. Masonry Committee).

H. Headwalls, Wingwalls, Inverts, Aprons.
  a. Where required.
  b. Design, Specifications, Construction.

I. Backfilling. Specifications; material, placing.

J. Pipe Line Crossings. Specifications.
  a. For inflammable substances, oil, gas, gasoline, etc.
  b. For substances under pressure, steam, water, etc.
  c. For substances not under pressure, sewage, etc.

K. Repairs to Existing Culverts.

4. Formation of the Roadway

A. Definitions.

B. Specifications.
  a. Alinement, grade, cross-section.
  b. Clearing and grubbing.
  c. Grading.
  d. Work in vicinity of operated tracks.
  e. General conditions.

C. Recommendations.
  a. Width of roadbed.
  b. Slopes.
  c. Allowance for settlement. Shrinkage. Subsidence.
  d. Ditches. Intercepting, for cuts; along fills. Side, in cuts.
  e. Berms.
  f. Units of payment.

D. Information.
  a. Good grading practice.
  b. Placing materials in embankments. Layers. Rolling. Terracing.
  c. Widening under traffic.
  d. Filling bridges.
  e. Track elevation and depression.
  f. Grade reduction.

5. Roadway Drainage

A. General. Scope. Importance.
B. Location Considerations.
C. Surface Drainage.
  a. Intercepting ditches for cuts.
  b. Intercepting ditches for fills.
  c. Side ditches.

D. Sub-surface Drainage.

- a. Soil moisture.
- b. Soils.
- c. Field tests for soil moisture.
- d. Water cut-off.
- e. Drainage of open soils.
- f. Drainage of impervious soils.
- g. Pipe drains.
- h. French or rock drains.

E. Special Problems During Construction.

- a. Prevention of soft spots and water pockets.
- b. Long cuts.
- c. Widening cuts and fills.
- d. Multiple tracks.
- e. Yards.
- f. Passenger stations.
- g. Highway grade crossings.

F. Maintenance.

- a. Ditches.
- b. Drains.
- c. Soft spots and water pockets.
- d. Slides.

6. Roadway Protection

A. Definitions.

B. Roadbed Protection.

- a. Concrete slab under ballast.
- b. Concrete slab with embedded ties.
- c. Concrete slab supporting rails directly.

C. Slope Protection.

- a. by Vegetation. Sodding and seeding. Bush and tree planting.
- b. by Surface blanketing. Willow mats. Grouting. Rip Rap.
- c. by Structural support. Struts. Piling.
- d. by Formation. Berms. Terracing. Widening cuts.
- e. Against burrowing animals.

D. Retaining Structures.

- a. Cribbing, Timber. Concrete.
- b. Walls. Dry Rubble. Masonry.

E. Protection Against Slides.

- a. Avalanche sheds.
- b. Snow sheds.

F. Removal of Blockades.

- a. Earth.
- b. Snow.
- c. Drift and debris.

G. Policing Right-of-way.

- a. Weed mowing and killing.
- b. Dust prevention.

7. **Tunnels**
    - A. Definitions.
    - B. Alinement and Grade.
    - C. Construction.
    - D. Ventilation.
    - E. Lighting.
    - F. Maintenance.

8. **Fences**
    - A. Definitions.
    - B. Fence Posts and Braces.
        - a. Wood.
        - b. Concrete.
        - c. Metal.
    - C. Fence Wire.
    - D. Erection.
    - E. Gates.
    - F. Stock Guards.
    - G. Protection Against Drifting Snow.
    - H. Protection Against Drifting Sand.

9. **Signs**
    - A. Definitions.
    - B. Roadway Signs Required.
    - C. Principles of Design and Rules for Use.
    - D. Economy of Various Materials.
    - E. Design of Signs.

Appendix B

(1) PHYSICAL PROPERTIES OF EARTH MATERIALS

H. W. Legro, Chairman, Sub-Committee; J. B. Akers, E. J. Beugler, P. D. Fitzpatrick, Albert Haertlein, G. E. Ladd, E. R. Lewis, L. S. Rose, H. M. Swope.

(A) GENERAL

Scope

Railway structures, in which term is included the track structure, are in the great majority founded on or within the unconsolidated earth materials, commonly called soil, that overlie bedrock in greatly varying depth, class, strata and content of moisture. This subject relates to the physical properties of earth materials—as found in their natural place and as used after disturbing from their natural position—affecting the stability of structures.

Importance

Proper selection or treatment of roadbed soils based on knowledge of their physical properties has a major influence on economical maintenance of track and operation of trains. Improvement of the quality or condition of the subgrade to adequately support the static load of the track and the heavy live loads at impact of rolling equipment will prevent excessive maintenance expense or, if maintenance be deferred, more rapid deterioration of the track which would adversely affect riding qualities, train schedules and the condition of equipment.

The foundations of heavy structures are subject to inevitable settlement. Utilization of data on the physical properties of bearing soils will permit economical design of structures that will settle uniformly and within allowable limits, or otherwise maintain stability.

(B) DEFINITIONS

Soil

The unconsolidated materials, diverse in character, overlying in varied layers the bedrock of the earth's crust and resulting from disintegration and decomposition of rock by mechanical and chemical processes through the influence of sun, air, water, ice and living and dead organic matter.

Note.—Strictly, the term "soil" applies to that portion only of the material overlying bedrock that will support plant roots, but engineering usage includes all the materials of the earth's mantle.

(Refer also to definitions on pages 365–370 of the Proceedings, Vol. 35, 1934).

(C) PHYSICS OF SOILS

(a) Soil Genesis[1]

The materials of the earth's soil originate in five ways. The first and most important of these is chemical alteration of individual minerals in solid rocks, aided by disintegration due to frost action. The second is disintegration of solid-rock surfaces, and rock fragments by abrasion of moving water and ice, and, in small degree, by winds, using rock fragments, large or small (down to the finest sand), as grinding tools. This action is effective also as between rock fragments themselves. The third is disintegration by wetting, or alternate wetting and drying, frost action, or chemical solution of binding material, in partially consolidated rocks, such as shales, soft sandstones, etc. The fourth is the production of "ash" or dust by volcanic explosions. The fifth is the accumulation of plant-growth material which, with some silt, constitutes peat formations.

Where weathered rock-products remain essentially undisturbed in the place of their origin, they are known as Residuary, and belong to the Class of Sedentaries. These, in the United States, are most widespread east of the Mississippi River and south of the area once ice-covered, during the Glacial Epoch. They are, when old, iron-stained to reddish and brownish colors. They are never truly stratified. The chemical decomposition of igneous rocks results in the production of salts which are largely carried away in solution. Other products, in large proportion, are various hydrous silicates of aluminum, which belongs in a general way to the clay group. These will be found mixed with residuary fragments, partially altered, of feldspars, hornblende, etc., and the quartz grains of the original rock. The latter are mostly unaffected by the chemicals in surface waters, and in time, after transportation, become a part of the vast amount of sand deposits which make up a considerable portion of the earth's mantle. The reason that clays and sands are so abundant is that the former is in itself a product of weathering processes and is subject, practically, to no further changes except those of abrasion, and that the latter, being essentially unaffected by the chemicals of surface waters due to original composition, also remain indefinitely, as a part of the mantle, immune to further change except that of being rounded and reduced in size by abrasive influences.

Another type of so-called residual material is only secondarily so. This consists of clays with an intermediate history of transportation until deposited in deep or quiet waters where limestones were being formed, and therein locked up until the whole formation was raised above sea level, the limestone dissolved, and the clay content left behind as a residuary deposit. Such are the fine, plastic clays often found in limestone caverns, and covering wide areas as an over-burden on under-lying limestone beds. The sticky, black soils of central Texas are examples of clays originating in this way. Another type of secondarily residual material is represented by clayey accumulations lying upon shale beds, and resulting from the physical disintegration of the compacted, and often slightly altered shales. In northern California, west of the Sierras, are many masses of this type of the earth's mantle.

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[1] Extracts from Landslides, Subsidences and Rock-Falls, Dr. George Edgar Ladd, AREA Bulletin, No. 377, July, 1935.

Still another type of sedentary material is classed as "cumulose". Examples of this are found in swamps and bogs. These, originally lakes and ponds, have become filled with coarse plant growth, infusorial, animalcule, and microscopic plant remains, to which may be added some clay and silt washed in from surrounding territory. Such material becomes peat.

Opposed to the formations of the Sedentary Class are the very large and widespread accumulations of the products of rock-weathering and rock-abrasion which have been transported by water, ice, and wind, and deposited, with more or less evidences of stratification, as extensive parts of the mantle. To this class belong glacial formations,—moraines, eskers, boulder clay (largely rock dust), some sand plains, and certain clay deposits (glacio-lacustrine); river deltas, terraces and flood plains; marine deposits; ancient lake formations; wind blown sand and silt deposits; volcanic ash; and "talus" on steep mountain slopes, where retained by benches, and, principally, at the foot of cliffs.

Examples of glacio-lacustrine clay beds are found in southern and western New York, parts of northern Pennsylvania, and in many areas surrounding the Great Lakes, notably in northern Wisconsin, and north and south of Lake Erie.

Wind-blown sand accumulations originating mostly on present or ancient shore lines are widely distributed in the United States. They are abundant on the Pacific Coast, and, on the Atlantic Coast, most strikingly in the Cape Hatteras, Long Island, and Cape Cod Regions. The Loess deposits of the valleys of the Missouri and Mississippi Rivers, from a little south of St. Louis north and westward, are in part wind-blown. The adobes, which occupy great areas in the arid states, particularly in the southwest, and which sometimes attain great thickness, are in part wind-blown.

Volcanic fragmental rocks (tuffs or ash) result from the comminution of rock by volcanic explosions. They are transported largely by air currents and may be deposited on land or in water. Subsequent movements and redeposition may occur as a result of water transportation. They may become part of a series of sedimentary formations, or they may become buried by lava flows. In any given position they may become partially or largely consolidated and, again become loose in texture and soft, through chemical decomposition. Many remnant beds of this material occur in Colorado, Kansas, Nebraska, Montana, and other western states.

(b) PHYSICAL PROPERTIES

The size and shape of soil grains, the relation of these grains in the soil mass, and the varying layers of soil masses are effects of geologic processes, and, largely with the presence of a variable amount of water, determine the physical properties of soils.

For purposes of identification for engineering uses, soils are variously classified in accordance with textural characteristics due to their origin and in accordance with their physical properties.

Certain basic physical properties of soils present in varied combination are responsible for all deformations of soils under stress that affect the stability of structures.

1. INTERNAL FRICTION is the resistance to motion of the particles of soil over each other caused by the roughness of the surfaces, and the shape and size of the individual

grains. It varies with applied pressure. Internal friction is high in sands and relatively low in clays.

2. Cohesion is the resistance to a force tending to separate two or more soil particles held together by minute moisture films, possibly supplemented by natural stickiness of colloids. It is independent of applied pressure. Cohesion is very low in sands and relatively high in clays.

3. Compressibility represents the change in volume of soil produced by pressure. It is slight in sands, where the bulky grains bear almost directly on adjacent grains, and much higher in clays, where the minute and scale-like grains are separated by capillary water which is squeezed out, producing volume change.

4. Elasticity is the property of soil to rebound after removal of load. It is almost entirely absent in sand with its bulky and rather rigid grains; it is present to varying degree in undisturbed clay, due principally to the scale-like, flexible particles and to flocculated, honeycomb arrangement of the particles. It is present in some soils containing organic matter, due to spongy structure.

5. Permeability determines the rate of consolidation of soils. The high permeability of sands permits almost immediate consolidation under load, while the small capillaries of clay retard the passage of contained water, resulting in a long-spread period of consolidation.

6. Capillarity of soil is contributed by the hair-fine spaces between the particles. The capillary movement of water is independent of gravitational force. The void spaces of sands are too large to act as capillaries except to slight degree. Higher capillarity, such as clays possess, contributes to the properties of cohesion, compressibility, elasticity and permeability. Capillarity is an important contributor to frost heaving of soil.

(c) Classification of soils

1. Mechanical analysis.

Classification of soils by mechanical analysis, by which soil samples are separated into fractions on the basis of grain size by screening or by sedimentation, has been devised by the United States Bureau of Public Roads as indicated graphically by the triaxial soil classification chart. (See Fig. 1 on page 305, Proceedings, Vol. 33).

2. Engineering properties.

While classification by mechanical analysis is of value for identification of soil constituents, it gives no clear-cut relation to the various physical properties of interest to the engineer. The shape of soil grains is not indicated by mechanical analysis, but is very important in influencing the physical properties of soil masses.

Soils with equal compressibility, equal permeability and equal consistency (cohesion for clays, and density for sands) will behave under load in an identical manner. A given soil to be used as foundation should be classified as to these three properties.

3. Uniform subgrade groups.

The United States Bureau of Public Roads has developed a classification of subgrade soils by which they are arranged in groups representative of constituent materials, physical properties and performance (Fig. 1). The groups follow—

Group A–1—Well graded material, coarse and fine, with good binder. Characterized by high internal friction, high cohesion, no detrimental shrinkage, expansion, capillarity or elasticity.

Group A–2—Coarse and fine material, poorly graded or with inferior binder. Characterized by high internal friction and high cohesion under certain conditions; may have detrimental shrinkage expansion, capillarity or elasticity.

Group A–3—Coarse material only with no binder. Characterized by high internal friction, no cohesion, no detrimental capillarity nor elasticity.

Group A–4—Silt soils without coarse materials, and with no appreciable amount of sticky colloidal clay. Characterized by variable internal friction, no appreciable cohesion, no elasticity and considerable capillarity.

Group A–5—Elastic silt soils. Characterized by variable internal friction, no appreciable cohesion, considerable elasticity and capillarity.

Group A–6—Clay soils without coarse material. Characterized by low internal friction, high cohesion when moisture content is low, detrimental shrinkage and expansion, and no elasticity; slow capillarity unless manipulated.

Group A–7—Elastic clay soils. Characteristics similar to Group A–6, but in addition possess elasticity.

Group A–8—Very soft peat and muck. Characterized by low internal friction, low cohesion, and high elasticity and capillarity.

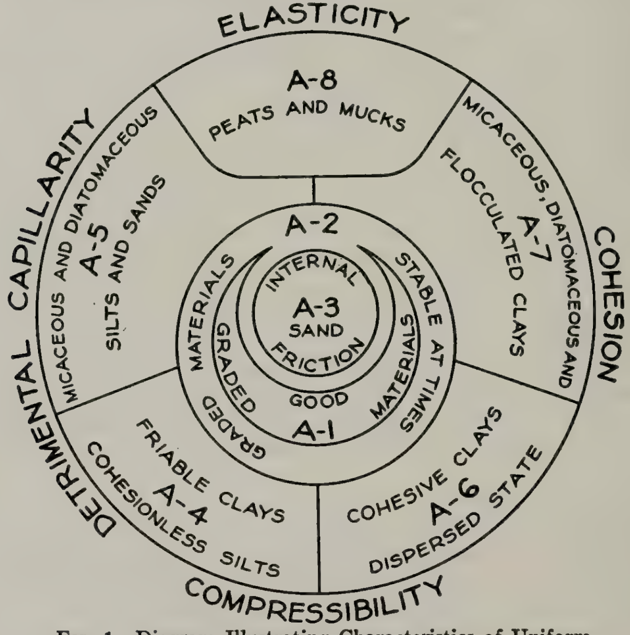


FIG. 1—Diagram Illustrating Characteristics of Uniform Subgrade Groups.

Appendix C

(2) NATURAL WATERWAYS

E. J. Bayer, Chairman, Sub-Committee; A. E. Botts, P. D. Fitzpatrick, J. A. Given, A. Haertlein, J. A. Noble, L. S. Rose, P. T. Simons.

This Sub-Committee has devoted its attention this year to the preparation of an outline of its field of work (see Appendix A) and a review of the material in the Manual which falls within its field, as a result of which recommends that the following be withdrawn from the Manual for the reasons indicated:

Definitions for "Flood Damage" and "Washout"—page 23.

Definitions for "Channel" and "Waterway"—page 25.

These definitions do not differ from the ordinary meaning of the words as found in a good dictionary.

Material on Waterways—pages 38, 39 and 40.

The Special Committee on Manual has asked that the figure on page 39 be redrawn for clarity. Before doing so the Committee would like to thoroughly review this entire subject.

Appendix D

(3) SERVICE LIFE OF CULVERTS

A. E. Botts, Chairman, Sub-Committee; L. L Adams, G. B. Farlow, D. A. Hultgren, W. J. Lank, M. C. Patton, C. S. Robinson, O H. Wainscott, F. E. Wiesner.

This subject was assigned in 1933, and after rating schedules had been prepared and data accumulated, a report was made to the convention of 1935 as information, with the recommendation that the subject be carried over in order that more culverts could be inspected.

The rating schedules and method of assemblying and calculating data were the same as shown on pages 318–325 of Volume 36 of the Proceedings.

Culverts inspected and reported are from all parts of the United States and Canada. The majority are from roads operating through the Middle Atlantic States and include quite a number of culverts in the coal fields where the water contains considerable acid.

The Committee wishes to acknowledge the help given it by the officers of the following railroads in assembling the data on 10,663 culverts of all types, together with the many photographs sent in:

Atchison, Topeka & Santa Fe Railway System
Atlantic Coast Line Railroad Company
Baltimore and Ohio Railroad
Canadian National Railways
Canadian Pacific Railway Company
Chesapeake and Ohio Lines
Chicago, Rock Island & Pacific Railway Company
Chicago, Milwaukee, St. Paul & Pacific Railroad Company
Erie Railroad Company
Florida East Coast Railway
Grand Trunk Western Railroad Company
Great Northern Railway Company
Illinois Central System
Kansas City Southern Railway
Louisville and Nashville Railroad Company
Maine Central Railroad Company
Minneapolis, St. Paul and Sault Ste. Marie Railway Company
Missouri–Kansas–Texas Railroad Company
Missouri Pacific Railroad Company
New York Central System
Norfolk and Western Railroad
Pennsylvania Railroad
Peoria & Eastern Railway
Pere Marquette Railway
Pittsburgh and Lake Erie Railroad Company
Richmond, Fredericksburg and Potomac Railroad Company
Seaboard Air Line Railroad
Southern Pacific Company
Southern Railway System

In last year's report the heading "Masonry" included all concrete arches, concrete boxes, stone arches, stone boxes and brick culverts. In this report these have been separated into two groups, those made of concrete and the other group including stone and brick culverts.

No attempt has been made to group culverts according to height of fill, character of water traffic, whether abrasive, corrosive, etc. Only age and present condition (rating) have been taken into consideration. Therefore, the expected life as calculated represents average conditions and may vary considerably for individual culverts.

The "Summary" shows the number of culverts inspected in each age group, average age, average rating for each and the expected life.

The method used in figuring the expected life is shown in the following example:

There were 1676 corrugated metal culverts inspected with an average age of 14.84 years, an average rating of 54.95 per cent. 100.00 — 54.95 per cent = 45.05 per cent of the life of culvert used up in 14.84 years. Dividing this percentage by the age gives:— $\frac{45.05}{14.84} = 3.04$ per cent of life used up in one year. Dividing this into 100 per cent gives:— $\frac{100.00}{3.04} = 32.89$ years expected life.

The following conditions affect the life of all classes of culverts included in this report: Poor foundations, abrasive hydraulic traffic and heavy loads, all tend to shorten the service life. The reverse of the above conditions is conducive to longer life. Special considerations applicable to each type of culvert are given in the following paragraphs:

(I) Corrugated Metal Pipe

The expected life of this type culvert is shown to be 33 years. It must be remembered that this life represents an average of all culverts inspected under all conditions. Where conditions are favorable, such as non-corrosive hydraulic traffic, water containing no acid or alkali, the life will probably be much longer, and on the other hand the life may be shortened under adverse conditions.

It will be noted that the rate of deterioration is quite uniform through the 20-year age group, while those in the 25-year group show a much higher rating. It is thought that the latter is due to grades of material having the maximum life while other grades have outlived their usefulness after 20 years of service.

(II) Concrete Pipe

The life of concrete pipe is shown as 67 years. To obtain the maximum life from this type of culvert, the most important considerations are the foundation and care of installation. The rate of deterioration as shown is fairly uniform and the Committee feels that this represents closely the life of concrete pipe in general.

(III) Vitrified Clay Pipe

The expected life of this pipe is shown in the summary as 70 years. Further reference to the summary will bring out the fact that there were only 57 culverts inspected which were 20 years or younger in age. This leads the Committee to the belief that this type of culvert has not been extensively used in the past 20 years, and that those culverts over this age represent the "survival of the fittest" under particularly favorable conditions.

(IV) Cast Iron Pipe

Cast iron pipe is calculated to have an expected life of 81 years. From the high rating given the older pipe culverts in this group it would appear that cast iron pipe shows very few progressive indications of deterioration after the first 30 years of its existence. Well constructed culverts of this material, in locations where destructive influences are at a minimum, should have a much longer life than indicated by our inspection. It will be noted that the rating is fairly uniform for the first 20 years and is then rather irregular from that point through the 45-year group. It is believed that this irregularity is due to different grades of pipe as in the case with the corrugated metal.

(V) Concrete Culverts

This group includes those culverts classed as concrete arch, concrete box and any other concrete structure either plain or reinforced. The expected life of this type is 92 years.

(VI) Masonry Culverts

All culverts constructed of stone or brick are included in this group. This type of culvert shows an expected life of 151 years. Where a high grade of stone is used in combination with a solid foundation and good workmanship, this figure is probably conservative. The 36 culverts shown in the 110-year group were built to carry a canal across streams running into a river parallel to it. After the canal was abandoned the culverts were used to support the roadbed and have rendered excellent service as attested by the average rating of 56.5 per cent.

Conclusions

From the information received and computed, the following average service life may be expected of existing culverts of the various materials:

1. Corrugated Metal Pipe— 33 years
2. Concrete Pipe — 67 years
3. Vitrified Clay — 70 years
4. Cast Iron Pipe — 81 years
5. Concrete Culverts — 92 years
6. Stone Masonry —151 years

These figures are the average expected life of the particular group of culverts inspected and are based on the method of rating adopted by the Committee. In all probability some of the culverts of each group:

1. were not designed for the loading they are now called on to carry;
2. were not of the type best suited to the particular location;
3. were not built to present day standards of workmanship and material;
4. did not have incorporated in them the features which experience has shown to be desirable in connection with each type of installation.

In view of the foregoing, the Committee is of the opinion that new culverts, of proper design and material, installed with care, and with consideration given to such auxiliaries as wing walls and aprons where necessary, will have a service life greater than that shown.

The service life of all culverts is materially affected by the following conditions:

1. Foundations and size (sufficient or scant), probable loading and care of installation.
2. Water to be carried; whether acid or alkaline.
3. The abrasive action of the materials carried by the water.
4. Corrosive action of atmosphere (salt air, acid fumes).
5. Periodical inspection and maintenance after installation.

· SERVICE LIFE OF CULVERTS SUMMARY

Age Group	Corrugated Metal			Concrete Pipe			Vitrified Clay			Cast Iron Pipe			Concrete			Masonry		
	No. Inspected	Avg. Age	Avg. Rating	No. Inspected	Avg. Age	Avg. Rating	No. Inspected	Avg. Age	Avg. Rating	No. Inspected	Avg. Age	Avg. Rating	No. Inspected	Avg. Age	Avg. Rating	No. Inspected	Avg. Age	Avg. Rating
0– 5	225	3.8	81.6	301	4.5	83.0	8	5.0	80.0	299	4.5	80.1	14	4.0	83.2			
10	435	8.0	73.4	539	8.0	82.3	8	8.4	73.7	540	8.5	77.8	119	8.0	85.3	13	9.3	65.4
15	188	14.1	41.7	318	13.3	78.6	17	13.6	68.2	271	13.8	71.2	151	13.0	80.5	4	12.7	82.5
20	446	19.4	31.7	257	18.2	77.5	24	18.8	52.1	653	18.8	62.5	168	18.5	74.7	13	19.3	68.1
25	323	23.3	50.7	219	23.4	72.9	98	24.3	51.9	603	24.1	72.8	279	23.4	77.0	65	24.5	76.5
30	46	28.2	69.8	157	28.2	72.9	118	28.1	55.7	729	28.5	68.7	270	27.9	73.6	109	29.1	66.1
35	13	31.3	17.7	47	31.5	70.9	126	33.3	48.0	416	33.6	74.2	64	32.7	70.4	169	33.5	63.3
40				4	37.8	52.0	48	39.3	61.9	171	37.9	76.6	12	38.8	85.0	141	39.1	69.4
45				2	45.0	90.0	49	43.9	42.9	235	43.3	65.4				74	43.6	64.0
50							31	48.4	47.1	27	47.7	73.3	1	46.0	75.0	146	49.5	70.8
55							37	54.2	38.9	67	54.0	69.7				280	54.3	67.6
60							18	58.9	49.5	2	56.0	75.0				80	58.4	62.8
65							10	63.0	57.0							140	62.9	62.5
70							1	66.0	40.0							45	66.2	70.0
75																17	73.8	82.4
80																7	77.0	72.9
85																45	83.1	49.3
90							1	86.0	30.0							14	86.1	68.6
95																56	94.0	63.6
100																2	100.0	75.0
105																2	104.0	75.0
110																36	109.0	56.5
Totals	1676	14.84	54.95	1844	14.17	78.82	594	33.79	51.94	4013	23.14	71.35	1078	21.11	77.07	1458	50.92	66.29
Expected Life	32.89 years			67.11 years			70.42 years			80.65 years			91.7 years			151.5 years		

Appendix E

(3) SPECIFICATIONS FOR CAST IRON CULVERT PIPE

A. E. Botts, Chairman, Sub-Committee; L. L. Adams, G. B. Farlow, D. A. Hultgren, W. J. Lank, M. C. Patton, C. S. Robinson, O. H. Wainscott, F. E. Wiesner.

This Committee reported last year (Vol. 36, p. 316) that the AREA specifications (Bulletin 327, p. 6) were little used. This year we have inquired into the comparative shell thickness, weight and cost of cast iron culvert pipe under AREA, American Water Works Association, and ASTM specifications, with the following results:

CAST IRON PIPE—COMPARATIVE DATA

		A. W. W. A.		*A. S. T. M.*		
Diam.	*A.R.E.A.*	*Class "A"*	*Class "B"*	*Standard*	*Heavy*	*Extra Heavy*
		NOMINAL THICKNESS				
12″	.44	.54	.62	.37	.37	.40
14″	.44	.57	.66	.37	.40	.46
16″	.50	.60	.70	.40	.46	.53
18″	.50	.64	.75	.42	.52	.60
20″	.50	.67	.80	.47	.57	.66
24″	.56	.76	.89	.56	.69	.80
30″	.69	.88	1.03	.70	.86	1.00
36″	.81	.99	1.15	.84	1.03	1.20
42″	.94	1.10	1.28	.98	1.20	1.40
48″	1.25	1.26	1.42	1.12	1.38	1.60
		ESTIMATED WEIGHTS				
12″	59.5	72.5	82.1	45.0	45.0	49.0
14″	67.2	89.6	102.5	52.0	57.0	65.0
16″	87.1	108.3	125.0	64.0	74.0	86.0
18″	97.8	129.2	150.0	76.0	95.0	110.0
20″	109.4	150.0	175.0	94.0	115.0	134.0
24″	147.1	204.2	233.3	135.0	167.0	195.0
30″	226.0	291.7	333.3	211.0	261.0	304.0
36″	309.1	391.7	454.2	304.0	374.0	438.0
42″	431.0	512.0	591.7	414.0	509.0	597.0
48″	655.1	666.7	750.0	540.0	669.0	779.0
		COMPARATIVE COST PER LINEAR FOOT				
	$46.00 Per Ton	*$43.00 Per Ton*	*$40.00 Per Ton*	*$46.00 Per Ton*	*$45.00 Per Ton*	*$43.00 Per Ton*
12″	1.37	1.56	1.64	1.04	1.01	1.05
14″	1.54	1.93	2.05	1.20	1.28	1.40
16″	2.01	2.33	2.50	1.47	1.66	1.85
18″	2.25	2.78	3.00	1.75	2.14	2.36
20″	2.51	3.22	3.50	2.16	2.59	2.88
24″	3.39	4.40	4.67	3.11	3.76	4.19
					$43.00 Per Ton	*$40.00 Per Ton*
30″	5.20	6.26	6.67	4.85	5.61	6.08
36″	7.11	8.42	9.07	6.99	8.04	8.76
42″	9.90	11.00	11.83	9.54	10.94	11.94
48″	15.05	14.32	15.00	12.42	14.35	15.59

It will be noted that pipe made to ASTM Specifications of a grade equal to or heavier than that of the AREA Specifications is uniformly much lower in cost, except for the 12 inch size where the heaviest ASTM grade is .04 in. (10 per cent) less in thickness and 23.4 per cent less in cost.

We therefore recommend that the AREA Specifications (Bulletin 327, p. 6, 7) be withdrawn from the Manual and recommend the use of ASTM Tentative Specification A 142–34T pending further consideration of this subject by the Committee.

Appendix F

(3) SPECIFICATIONS FOR CORRUGATED METAL PIPE—1935

A. E. Botts, Chairman, Sub-Committee; L. L. Adams, G. B. Farlow, D. A. Hultgren, W. J. Lank, M. C. Patton, C. S. Robinson, O. H. Wainscott, F. E. Weisner.

MATERIAL

Base Metal

1. Corrugated metal pipe shall be fabricated from corrugated galvanized sheets, the base metal of which shall be made by the open-hearth process and shall conform in chemical properties to one of the classes listed in Table 1. The class of metal desired shall be designated in the invitation for bids.

Table I

Chemical Composition by ladle analysis
(Position of Base Metals does not indicate preference)

	Kind of Base Metal					*Tolerance by Check Analysis of Finished Sheets*
Elements	*Pure Iron*	*Copper Bearing Pure Iron*	*Copper Iron*	*Copper Molybdenum Iron*	*Copper Steel*	
Carbon, Max. per cent						
Manganese, Max. per cent						
Phosphorus, Max. per cent	.015	.015	.015	.015		
Sulphur, Max. per cent	.040	.040	.040	.040	.050	.010
Silicon, Max. per cent						
Copper, Min. per cent		.20	.20	.40	.20	.02
Molybdenum, Min. per cent				.05		
Sum of first 5 elements, Max. per cent		.10	.25	.25	.70	.04
Sum of first 6 elements, Max. per cent	.10					.04

Rivets

2. All rivets shall be of the same material as the base metal specified for the corrugated sheets. They shall be thoroughly galvanized, or sherardized.

Weight of Zinc Coating

3. The base metal sheets shall be galvanized on both sides by the hot dip-process. A coating of prime western spelter or equal shall be applied at the rate of not less than 2 ounces per square foot of sheet, or 1 ounce on each side. If the average zinc coating, as determined from the required samples, is less than 2 ounces of zinc per square foot of sheets, or if any sample shows less than 1.8 ounces of zinc per square foot of sheets, the lot sampled shall be rejected. The finished sheets shall be of first class commercial quality, free from injurious defects, such as blisters, flux and uncoated spots.

Sampling

4. Chemical analysis of the base metal of the finished sheet, when required, shall be made of the samples taken for weight of coating test. For testing coating of sheets before fabricating, a sample strip about 3 inches wide shall be cut crosswise the full width, and within 6 inches of the end, from one sheet of each lot of the same identification symbol. From this strip and along the newly sheared edge samples 2¼ inches square shall be cut from the middle and near each end. For testing coating of fabricated pipe, at least one sample 2¼ inches square shall be selected from each 20 pipes of a shipment, provided that not less than three samples, each from a different section, shall represent any one shipment.

Analysis of Finished Sheet

5. When not otherwise provided, chemical analyses, when required, shall be made in accordance with the methods of the American Society for Testing Materials, Serial Designation A 33–24.

Tests for Zinc Coating

6. The tests for weight of zinc coating shall be made in accordance with the hydrochloric acid-antimony chloride method as described in ASTM Standard Method A 90–33.

Identification

7. No pipe will be accepted unless the metal is identified by a stamp on each sheet showing:

(1) Name of sheet manufacturer
(2) Name of brand and kind of base metal
(3) Gage number
(4) Weight of zinc coating
(5) Identification symbols showing $\left\{\begin{array}{l}\text{(heat number)}\\\text{(pot number)}\end{array}\right.$

The identification stamp shall be placed on the sheets by the manufacturer of the sheets in such a way that when the sheet is fabricated into a pipe section the identification shall appear on the outside of each sheet.

Pipe ordered for culverts shall have a metal tag, of durability equal to that of the pipe, riveted to the inside of the pipe at the upstream end of the section of pipe which will constitute the inlet end of the culvert. This tag shall suitably identify the kind of base metal by name or by abbreviation which will enable the purchaser readily to determine which of the classes in Table I the base metal complies with. The tag shall also show the year of fabrication of the pipe. Pipe ordered for use as drains or other long lines shall have the identification tag attached on the outside of the pipe at least once in each 300 feet and in such location that when the pipe is properly installed the tags will be near the top of the pipe.

Corrugations

8. Corrugations shall not be less than 2¼ inches nor more than 2¾ inches center to center. The corrugations shall have a depth of not less than ½ inch.

Gage Determination and Tolerance

9. The gage of sheets shall be determined by weight only. The tolerances shown below shall apply to all gages of metal used in the manufacture of pipe covered by this specification, when the sheets are inspected in the shop before fabrication. When shop inspection is not made, gage shall be determined by weight of finished pipe, as specified in Section 11. The gage weight tolerances shall be those given in Table III of the Standard Specifications for Zinc-coated (galvanized) sheets, Serial Designation A 93–27, of the American Society for Testing Materials and subsequent revisions. The portion of this table which applies to the sheets provided for in this specification is as follows:

Permissible tolerances in weight of sheets, plus or minus, in percentage of theoretical weight.

All of one gage and size in shipment[1]	*Single Packages*	*Single Sheets*
5.0	7.0	10.0

[1] All of one gage and size in shipment shall apply to lots of not less than 6,000 pounds.

The weights of galvanized sheets shall be as follows, subject to above tolerances:

Galvanized Sheet Gage Number	*Weight in Pounds Per Square Foot*
16	2.656
14	3.281
12	4.531
10	5.781
8	7.031

FABRICATION

Shape

10. Corrugated pipe furnished under this specification shall be of the full circle, riveted type, with lap joint construction.

Dimensions and Weights

11. The length of sheets, widths of laps, gages, and computed weights per linear foot of the finished pipes shall be as specified in the following table. The dimensions given for diameter of pipe are nominal. The average weight per linear foot of a finished pipe, exclusive of end finish, shall not underrun the computed weight specified by more than 5 per cent.

Nominal Diam. Inches	*Length of Sheet Before Forming Inches*	*Minimum Width of lap Inches*	*Computed Weight per Linear Foot of Finished Pipe Exclusive of End Finish (Based on 20' length of Pipe) Pounds*				
			Galvanized Sheet Gage Number				
			16	*14*	*12*	*10*	*8*
8	28½	1½	7.3				
10	35	1½	9.0				
12	41	1½	10.5	13.1			
15	50½	1½	12.9	16.1			
18	60	1½	15.3	19.1	26.4		
21	69½	1½	17.7	22.1	30.6		
24	80	2	20.4	25.2	34.7	44.2	
30	98	2		30.9	43.0	54.8	
36	117	2		37.1	51.0	65.4	79.4
42*	137	3		43.6	59.5	76.8	93.2
48*	156	3			68.0	87.4	106.1
54	1–80) 1–98)	3			77.8	99.4	120.7
60	2–98	3				108.9	133.5
66	1–98) 1–117)	3				120.6	146.4
72	2–117	3				130.4	159.3
78	1–117) 1–134)	3				142.4	172.8
84	2–137	3					185.2

* Two sheets may be used by allowing sufficient total sheet lengths to provide for an additional longitudinal lap.

Rivets and Riveting

12. Rivets shall be of the following diameters and lengths for the gages specified:

	Diameters	*Lengths*	
		Two Thicknesses of metal	*Three Thicknesses of metal*
No. 16-gage material	5/16"	⅝"	⅝"
14 " "	5/16	⅝	¾
12 " "	⅜	¾	⅞
10 " "	⅜	⅞	1
8 " "	⅜	⅞	1⅛

All rivets shall be driven cold in such a manner that the plates shall be drawn tightly together throughout the entire lap. The center of no rivet shall be closer than twice its diameter from the edge of the metal. All rivets shall have neat, workmanlike and full hemispherical heads or heads of a form acceptable to the engineer, shall be driven without bending, and shall completely fill the hole. Longitudinal seams shall be riveted with one rivet in the valley of each full corrugation. The longitudinal seams of all pipe 42 in. or more in diameter shall be double riveted. Where double riveting of the longitudinal seam is required, the distance from center to center of the two rows of rivets shall be not less than three diameters. Circumferential, shop-riveted seams shall have a maximum rivet spacing of 6 in., except that six rivets will be sufficient in 12-inch pipe.

Coupling Bands

13. Unless otherwise specified, field joints shall be made with bands. The sheets used for the bands shall be of the same base metal as that in the pipe. Except when No. 16 gage metal is used for the pipe, the bands may be two gages lighter than the gage used for the pipe.

The bands shall be not less than 7 in. wide for diameters of 8 in. to 30 in., inclusive; not less than 12 in. wide for pipe with diameters 36 in. to 60 in., inclusive; and 24 in. wide bands shall be furnished for pipe in diameters 66 in. and over. Bands shall be so constructed as to lap on an equal portion of each of the sections to be connected, and preferably shall be connected at the ends by galvanized angles having minimum dimensions of 2 in. × 2 in. × $\frac{3}{16}$ in. The 7 in. wide bands shall be fastened by at least two galvanized bolts not less than ½ in. in diameter. The 12 in. bands shall be connected by three such bolts, and the 24 in. bands by five ½ in. bolts. Other equally effective methods of connecting the coupling bands may be used if approved by the Engineer.

Workmanship

14. It is the intent of this specification that in addition to compliance with the details specified herein the completed pipe shall show careful finished workmanship in all particulars. Among others the following are defects constituting poor workmanship and the presence of any of them in any individual pipe or in general in any shipment shall be sufficient cause for rejection:

(1) Uneven laps.
(2) Elliptical shaping.
(3) Variation from a straight center line.
(4) Ragged or diagonal sheared edges.
(5) Loose, unevenly lined or spaced rivets.
(6) Poorly formed rivet heads.
(7) Illegible brand.
(8) Lack of rigidity.
(9) Bruised, scaled, or broken zinc coating.
(10) Dents or bends in the metal itself.

Mill or Shop Inspection

15. If the purchaser so elects, he may have the material inspected at the rolling mill or the culverts inspected in the shop where they are fabricated. He may require from the mill that a chemical analysis be made of any heat. The purchaser, or his representative, shall have free access to the mill or shop for inspection purposes, and every facility shall be extended to him for this purpose. Any material included in any shipment which has been rejected at the mill or shop will be considered sufficient cause for the rejection of the entire shipment.

Field Inspection and Acceptance

16. The field inspection shall be made by the purchaser, who shall be furnished by the seller with an itemized statement of the sizes and lengths of pipe in each shipment. This inspection shall include an examination of the pipe for deficiencies in length of sheets used, nominal specified diameter, net length of finished pipe, and any evidences of poor workmanship as outlined above. The inspection may include the taking of samples for chemical analysis and determination of weight of zinc coating. If 25 per cent of the pipe in any shipment fails to meet all the requirements of this specification, the entire shipment may be rejected.

It is recommended that this specification be adopted for the Manual, replacing the present specification in supplemental Bulletin 327, pages 1 to 6 inclusive.

Appendix G

(4) FORMATION OF THE ROADWAY

Paul Chipman, Chairman, Sub-Committee; L. C. Frohman, H. H. Harmon, C. T. Jackson, H. T. Livingston, C. S. Sample, A. W. White, W. H. Woodbury.

REVISION OF SPECIFICATIONS

The Specifications for the Formation of the Roadway (1929 Manual, pages 28–36) in substantially their present form were adopted over thirty years ago; since which time the art of grading, like many matters involving transportation, has been revolutionized by the substitution of the gas engine for horse power. However, specifications deal with requirements rather than methods, and these are little changed; although the importance of well built embankments, well drained cuts and certain other features are now more fully appreciated. Revisions necessitated by advance in the art are therefore not as numerous as might casually be assumed.

No grading specifications can be drawn that will be applicable in all respects to every job. Special conditions will necessitate certain modifications, as will differences in the practice and policy of railroads and diversity of soil and climatic conditions. The most that can be done is to produce a set of specifications that will apply to most grading jobs and require a minimum of modification for the others.

The changes now proposed are based, in large part, on a study of the grading specifications of a number of railroads, made by H. T. Livingston in 1934, as Chairman of the Sub-Committee which investigated the extent of adherence to the present specifications.

The principal differences in the present and proposed readings are as follows:

Article 4 (new) specifies width of cut including ditches, instead of excluding them.

Articles 6–12 incl. (new), subjects of "Clearing" and "Grubbing" are combined under one heading. The unit of measurement recommended is the acre instead of 100 feet square.

Article 10 (new), minimum fill over stump tops is made 3 ft. instead of 2½ ft.

Articles 16, 17 and 18 (new) make definition of classifications more specific.

Article 20 (new) provides for removal of unsuitable material in bottom of earth cuts.

Article 22 (new), relating to blasting, has been added.

Material relating to Borrow, old Articles 26, 43, 44, 45, and 46, has been condensed into two new articles, Nos. 24 and 25. Second paragraph of old Article 26 has been omitted, being in the nature of a recommendation.

Article 34 (new), "Rolling", has been added.

Article 37 (old), Embankments Across Swamps, has been revised to provide for methods other than corduroy.

Article 41 (old), Embankments Over Masonry, has been made more specific.

Article 45 (new), Haul, is a condensation of old Article 50, revision of 1929 Manual.

Article 47 (new), Moving Company Tracks and 54 (new), Cleaning Up, have been added.

SPECIFICATIONS FOR THE FORMATION OF THE ROADWAY—1935

ALINEMENT, GRADE, CROSS-SECTION

Alinement

1. The center of the roadway shall conform in alinement to the center stakes.

Subgrade

2. The grade line on the profile denotes ultimate subgrade on the center line, and this term indicates the top of embankments or the bottom of excavations, ready to receive the ballast.

Cross-Section

3. The roadway shall be formed to the section, slopes and dimensions shown upon the standard drawings, or to such modifications thereof as may be from time to time directed.

Width of Roadway

4. When completed, the roadway shall conform to the finishing stakes and shall be of the following widths at subgrade, for single track, viz:

Embankments: ....(......) feet
Excavations: ....(......) feet

inclusive of the width necessary for normal ditches.

Grading for additional tracks and station grounds shall be of such widths as may be directed.

Slopes

5. The slopes of embankments and excavations shall be of the following inclinations, as expressed in the ratio of the horizontal distance to the vertical rise:

Embankments:		One and one-half to one.
Excavations:	Common	One and one-half-to one.
	Loose Rock	One-half to one.
	Solid Rock	One-quarter to one.

Slopes may be varied according to circumstances and shall be made as directed in each particular case.

CLEARING AND GRUBBING

Extent of Clearing

6. The right-of-way, station grounds and land provided for borrow pits, except any portion thereof that may be reserved, shall be cleared of all trees, brush and perishable materials of whatsoever nature.

Stumps

7. Where the area cleared is not to be grubbed, the height of stumps above ground shall not exceed the smallest diameter of the stump at its top and in no case shall the height exceed eighteen (18) inches.

Reserved Timber

8. If directed, trees reserved shall be made into logs, piling, ties or posts. This material shall be neatly piled at designated places and all waste material burned. Payment for such service shall be made in appropriate units.

Buildings

9. Where buildings or other structures are to be removed, payment shall be made for their removal at a price to be agreed upon, unless the Company shall elect to make other arrangements.

Extent of Grubbing

10. Stumps shall be grubbed wherever excavations occur, also between the slope stakes of embankments where fill over stump tops would be less than three (3) feet, and elsewhere if directed.

Clearing and Grubbing in Advance

11. The work of clearing shall be kept at least one thousand (1000) feet and of grubbing at least three hundred (300) feet in advance of grading.

Disposal

12. Unless reserved, all perishable material shall be burned or removed from the Company's land without injury to adjoining property.

Measurement

13. Measurement of clearing and grubbing and payment for the same shall be by units of one acre or fraction thereof, actually cleared or grubbed.

GRADING

14. The term "Grading" in these specifications includes all excavations and embankments for the formation of the roadbed, ditching, diversions of roads and streams, and all similar works pertaining to the construction of the railway, its sidetracks and station grounds.

Classification

15. All material excavated shall be classified as "Solid Rock", "Loose Rock", "Common Excavation", and such additional classification as may be established before the award of the contract.

Solid Rock

16. Solid rock shall include all rock in solid beds or in compact, stratified masses which, in the judgment of the Engineer, should be removed by continuous blasting. Boulders or detached rock, measuring one (1) cubic yard or more, shall be classified as solid rock.

Loose Rock

17. Loose rock shall include all detached rock or boulders measuring more than one cubic foot and less than one cubic yard, and shale, slate, soapstone, cemented gravel and other rock which, in the judgment of the Engineer, can be removed without blasting, though blasting may occasionally be resorted to.

Common Excavation

18. Common excavation shall include such materials as are commonly called earth, loam, clay, muck, sand, gravel, gumbo, hard-pan, small boulders, angular rock fragments and all other materials of every description not specially classified.

No classification or allowance shall be made for loose or solid rock in borrow pits unless specific written instructions are given to the contrary; it being the intent and meaning of these specifications that all borrowed material shall be classified and paid for as common excavation.

Finishing Slopes

19. Slopes of all excavations shall be cut true and straight, and all loose stones, boulders, roots, stumps and unstable ground in the slopes shall be removed. Under-cutting of slopes will not be permitted except upon the written consent of the Engineer.

Excavation Below Subgrade

20. Rock excavation shall be taken out to a depth of .... (.......) inches below subgrade and be refilled to subgrade with approved material. Unstable material in the bottom of a cut shall be removed to the depth directed and such excavation shall be refilled to subgrade with approved material. The measurement of excavation shall be made to the bottom of the material removed; but no payment shall be made for refilling, over and above the contract price for excavation of the material used for that purpose.

Excess Excavation

21. The classification of the material excavated shall be in accordance with its condition at the time of its excavation, regardless of prior conditions. The measurement of the material shall be the original space occupied, regardless of the classification. Excavation in excess of the authorized cross-section shall not be included in the measurement except in removal of unpreventable slides.

Blasting

22. When explosives are used in rock excavation, the charges shall be so proportioned and placed that they will not loosen the rock outside of the excavation lines called for on the drawings or as provided for in the specifications. If the rock below the line of the side slopes should be loosened by blasting to such an extent as to render it liable to slide or fall, such loosened rock shall be removed by the Contractor without extra compensation, except as provided for in Article 20.

Where blasting is likely to endanger persons or property, the Engineer shall have the power to prescribe and enforce such rules and regulations as may be necessary; but the prescribing or failure to prescribe such rules and regulations shall not relieve the Contractor from any responsibility under the contract.

Disposition of Materials

23. The materials from excavations incident to the construction of the roadbed, ditches, channels and roadways shall, so far as they are suitable, be used in forming the embankments. Frozen or other unsuitable material shall not be permitted to enter into the composition of embankments. Where earth and rock are deposited in the same fill, they shall be placed as directed by the Engineer.

Where the quantity excavated exceeds that required to make the embankments to standard cross-section, the surplus shall be used to widen the embankments uniformly along one or both sides, unless other disposition is shown on the profile or directed in writing. Where wasting is so authorized, it shall not be started until the location, height and form of waste bank has been approved.

Borrow

24. Where the quantity of material from the cuttings of standard cross-section is not sufficient to form the embankments as specified, the deficiency shall be made up by widening the cuttings on one or both sides to the extent and with the slopes directed, unless the use of borrow pits is indicated on the profile or authorized in writing.

Borrow Pits

25. Borrow pits shall not be excavated before they have been cross-sectioned and shall be of regular form, in order to admit of accurate measurement. Borrow pits shall be drained and no depressions left that will hold water. Side slopes of borrow pits shall be one vertical to one and one-half horizontal, except where otherwise directed.

A berm of the original unbroken ground, with width of not less than .... (.......) feet, shall be left between the slope stakes of embankment and inner edge of borrow pit. A berm of not less than .... (.......) feet shall be left between the outer edge of borrow pit and property line.

Land for Borrow Pits

26. The available borrow on the Company's land is indicated in location and quantity on the profile plans. If additional borrow is required, or if alternative borrow is desired by the Contractor, it shall be obtained by him at his own expense from a source approved by the Engineer. Before excavating material from such outside borrow pit, the Contractor shall secure from the owner thereof and deliver to the Engineer a written release to the Company from all damages arising from such use.

Approximate Quantities Shown

27. The classification and quantities shown on the profile exhibited for distribution of material are approximate only, and shall in no way govern the final estimate. The Company reserves the right to increase or diminish the quantities given without affecting the contract unit prices for the various parts of the work.

Reserving Gravel

28. Gravel, stone or any other material suitable for special use of the Company, which is found within the excavations, shall, when required, be reserved and deposited in convenient places on the right-of-way, as directed. Other suitable material in the vicinity shall be substituted, as required, to complete the embankments.

Berm in Rock Cuttings

29. A berm of .... (.......) feet shall be left between the top of slope of rock cuttings and toe of slope of the overlying earth.

Intercepting Ditches

30. Intercepting ditches, when ordered, shall be made at the top of the slopes of all cuttings and along fills where the ground falls toward the center line. These ditches must diverge sufficiently to prevent erosion of the embankment. The cross-sections and locations of such ditches shall be as designated. If required, they shall be excavated in advance of opening the cutting.

Ditches in Cuttings

31. Ditches shall be formed at the bottoms of the slopes in cuttings, according to cross-sections shown upon the plans, or such modifications thereof as may be directed. They shall be neatly made, clear of obstruction, and at the lower ends must diverge sufficiently to prevent erosion of the adjoining embankments.

Subdrains

32. Pipe subdrains shall be constructed of the material, size and design, and in the location shown on the plans, and to the depth and grade established for them. The cross-section of the trenches shall conform with the plans, and the trench shall be excavated and the pipe laid to true line and grade. Sufficient cribbing or shoring must be used to prevent caving of the trench excavations. The excavated material shall be disposed of as directed. All trenches must be backfilled with an approved permeable material, kept free from cementing, clogging or extraneous materials. The finished section of the backfill shall conform with the plans. Measurement and payment for such drains shall be made by the linear foot, according to the diameter of the pipe and its located depth, including excavation, backfilling and disposal of excess material.

Formation in Layers

33. When directed, embankments shall be built in horizontal layers of .... (.......) feet in thickness. The layers must be the full width of the embankment, without depressions between slopes, built to the true slope, and not widened with loose material from the top. The most suitable material shall be reserved for finishing the surface. Large stones shall not be permitted within a depth of .... (.......) feet below subgrade.

Rolling

34. When directed, embankments placed in layers shall be thoroughly compacted by rolling each layer with a self-propelled roller weighing not less than .... (.......) pounds per linear inch. Additional payment for such compaction shall be made by the cubic yard, measured in excavation.

Shrinkage, Etc.

35. Embankments shall be carried to such heights above subgrade and to such increased widths as may be deemed a necessary provision for shrinkage, subsidence and erosion. As the embankments become consolidated, their sides shall be carefully trimmed to the proper slopes, and the embankments must be maintained at their proper heights, dimensions and shapes until the work is finally accepted.

Embankments on Slopes

36. Where an embankment is to be placed on sloping ground, the surface shall be deeply plowed or stepped. Whenever directed, boggy or unsuitable material shall be excavated so that the embankment shall be on a firm foundation.

Snow and Ice

37. Snow and ice shall be removed before placing grading material.

Embankments Across Swamps

38. In crossing bogs or swamps of unsound bottom, the Engineer may require special construction, designed to meet the conditions. In such cases, a special price will be agreed upon.

Filling Trestles

39. In forming embankments from or about trestles, the material shall be spread uniformly, without depressions between the slopes, and shall be thoroughly compacted between the trestle bents and around and under all parts of the structure. No part of the trestle shall be left in the embankment within .... (.......) feet of the ultimate subgrade.

Embankments at Trestles

40. Embankments abutting the ends of trestle bridges shall be brought forward upon the structure a distance of at least .... (.......) feet, with increased width of .... (.......) feet in order to form a full roadbed.

Finishing Subgrade

41. The subgrade shall be compact and finished to a true sloped or crowned surface as called for by the plans, and must leave no depression or irregularity which will hold water or prevent proper drainage.

Embankments over Masonry, Etc.

42. In backfilling about or against or in filling over masonry or other structures, the material shall be deposited in layers not more than .... (.......) inches thick, sloping away from the structure, with each layer carefully tamped. Only the best available material shall be used for this purpose. Wet or impervious materials shall not be used for filling against or over masonry. The filling over arches shall be deposited simultaneously from both sides. Large stones shall not be placed within .... (.......) feet of the extrados of any arch. Water proofing must be kept intact, undamaged by filling operations. The cost of such work will be covered by the unit price paid for excavation, unless otherwise provided in the contract.

Measurement of Grading

43. Grading shall be measured by the cubic yard of excavation, except that material obtained from sources that do not permit accurate measurement in excavation may be measured in embankment or in cars, with such proper allowances for change in bulk as shall be agreed upon in advance.

Work Included

44. The completed work shall include the excavation of the material by whatever method is adopted, the loading, transportation and deposit of the same in the place or places designated, and in the manner prescribed, the plowing or benching of slopes and the finishing of the roadbed, slopes and ditches, and all other work which may be incident to the completion of the grading.

Haul

45. Unless otherwise specified, the contract prices for grading cover all haul of material excavated. If a price for overhaul is provided in the contract, the unit of measurement shall be one cubic yard, measured in excavation, hauled one hundred (100) feet. Payment in such units shall only be made for haul in excess of .... (......) feet. Haul shall be the distance along the center line of the roadway, or along the most direct practicable route, between the center of mass before excavation and the center of mass as finally placed.

WORK IN VICINITY OF OPERATED TRACKS

Precautions for Safety of Trains and Tracks

46. The work shall be so arranged that there will be no delay or interference in any manner with the operation of trains. Blasting will not be permitted close to main tracks, nor shall the Contractor transport material on or between the Company's tracks nor closer than a safe distance therefrom, except when authorized.

Whenever the work as authorized affects the safety of trains or tracks, the Company shall take such precautions as it may deem advisable to insure safety, and the cost thereof shall be charged to the Contractor.

Moving Company Tracks

47. Moving the Company's tracks for the Contractor's convenience shall only be done at the Contractor's expense by Company forces or under Company supervision and when authorized in writing.

Plowing Slopes

48. Wherever an existing embankment of .... (.......) feet in height or over is raised or widened, the slope of the existing embankment shall be deeply plowed in order to bind the new material thoroughly to it.

Crossings

49. When a crossing is necessary to transport material across an operated track, the location and construction of the crossing must be approved and it must be maintained by the Contractor to the Company's satisfaction.

Watchmen, Operators and Flagmen

50. Watchmen, operators and flagmen, both day and night, shall be furnished by the Company at the places it may consider necessary for the safety of the Company's trains and property, and the cost shall be charged to the Contractor. The providing of watchmen, operators and flagmen shall not relieve the Contractor from liability.

Safety Signals

51. All signals necessary to insure the safety of trains shall be placed, maintained and operated by the proper department of the Company. All instructions regarding their observance must be strictly obeyed.

GENERAL CONDITIONS

Temporary Fences

52. Previous to or during the work of grading, suitable temporary fences shall be erected and maintained, if necessary, in order to prevent trespass upon the railway or damage to adjoining property.

Roads and Crossings

53. Suitable roads and crossings for public and private use shall be provided and maintained by the Contractor where necessary within the limits of the work. All necessary appurtenances shall be provided.

Cleaning Up

54. Before the work is finally accepted, the Contractor shall at his own expense clear away from the Company's property, as well as from public and private roads and the channels of streams and ditches, all rubbish and surplus material and all Contractor's tools, equipment and other property.

It is recommended that these revised Specifications for the Formation of the Roadway be adopted for publication in the Manual to replace the present specifications (1929 Manual, pages 28–36).

The following cross reference lists of article numbers will permit ready comparison of the old and new specifications:

Article Numbers:

Old—See	*New*	*Old—See*	*New*	*Old—See*	*New*	*Old—See*	*New*	*Old—See*	*New*
1	1	13	10	25	23	37	38	49	18
2	2	14	11	26	24	38	39	50	45
3	3	15	13	27	27	39	40	59	46
4	4	16	14	28	28	40	41	60	46
5	5	17	15	29	29	41	42	61	48
6	6	18	16	30	30	42	26	62	49
7	12	19	17	31	31	43	25	63	50
8	7	20	18	32	32	44	25	64	51
9	11	21	19	33	23	45	25	65	52
10	8	22	20	34	33	46	43	66	53
11	9	23	21	35	35	47	44	67	37
12	13	24	23	36	36	48	43	—	—

Old Articles 50 to 58 on Tunnel Excavation have been omitted as not properly a part of these specifications. Old Article 68 has been omitted as unnecessary. New Articles 22. Blasting, 34. Rolling, 47. Moving Company Tracks, and 54. Cleaning Up, contain material not found in the old specifications.

Appendix H

(5) ROADWAY DRAINAGE

H. M. Swope, Chairman, Sub-Committee; L. J. Drumeller, D. A. Hultgren, H. W. Legro, M. C. Patton, W. C. Pruett, C. S. Sample, F. E. Wiesner.

This Committee has continued the study of roadway drainage particularly "Soft Spots and Water Pockets". The subject of roadbed drainage has been investigated during the past several years and the results of this study have been adopted for the Manual as recommended practice during the years 1931 to 1934, inclusive. The Committee has endeavored to ascertain scientific progress made by railroads within this field. Engineers representing many railroads were contacted with this object in view. This investigation has not disclosed any improvements to add to, or alterations to make in the recommended practices adopted by the Association during the past five years.

The treatment of soft spots and water pockets is of great importance to the railroads. It is therefore desired to keep in contact with the developments and improvement in methods used in their treatment. Information concerning any such developments is solicited by the Committee from the members of the Association for future study.

One railroad reports a method of opening up drainage of water pockets in fills which is of interest. This district operates day trains only and the work was carried on at night, closing up the work each morning for the scheduled traffic. A caterpillar dragline, operated upon the ties, excavated the side of the fill perpendicularly from the ends of ties and in some instances slightly undercutting them. The excavation continued until the material was removed to the depth of the water pockets, and was cast over next to the right of way fence. Occasionally some hand work was required to insure removing all of the clay from the edge of the pocket to give it complete drainage. This operation was followed by a train of air dump cars placing coarse sand, restoring the embankment to a normal section, the sand affording continuous drainage for water reaching the pockets. Some of the water pockets were 8 to 10 ft. deep. The same method was used in some of the more shallow cuts. A similar treatment was given a low embankment by this same railroad. The shoulders were plowed down with work train using ditching or plowing equipment. It was possible to plow off the embankment in this manner to the bottom of the water pockets and restore the shoulder with mine cinders. Both of these operations are reported as proving highly successful. This same railroad reports the treatment of a 50-ft. sliding fill by the tunneling method. 36″ pipe tunnels were driven into the base of the fill to a point directly below the center of the track and then turned at right angles in each direction carrying the tunnels longitudinally under the track. 6″ pipes were driven out in different directions from this central tunnel to relieve the water pockets. The tunneling operations were generally carried on ten or twelve feet below the surface of natural ground and all lead into one main pipe that carries off the drainage. After three years' service this system has proven very successful. The drainage flow is continuous and the movement of the fill has entirely stopped.

The method of jacking pipe into fills to tap water pockets has been used by some railroads. To successfully use this method it is necessary to obtain accurate soundings to determine the elevation of the bottom of the pockets and penetrate them at this point with the perforated pipe. Small perforated creosoted wood boxes are being used as a measure to prevent water pockets. They are placed in a trench at an elevation from two to four feet below the bottom of the track ditch. The trench is backfilled with a pervious material and serves to intercept the water. One company reports making these boxes of small size, 4 in. × 4 in., in order to keep them more nearly filled with water to prevent rotting. Satisfactory results by the use of this method are reported.

This report is offered as information.

Appendix I

(7) TUNNELS

F. W. Alexander, Chairman, Sub-Committee; L. L. Adams, G. B. Farlow, J. A. Given, C. S. Robinson, J. B. Trenholm, O. H. Wainscott.

Your Committee first reviewed the material in the Proceedings and Manual, not only that covered by reports of the Roadway Committee but also of other Committees, as there is considerable valuable information in connection with tunnels under their reports. The next step was to look up and review all published articles on railway tunnel construction, ventilation and maintenance covering the last 25 years. Some 160 articles were looked up and reviewed.

COLLABORATION

The study of the subject indicated it would be necessary to collaborate with several other committees. Contacts have been made with the following:

Committee XVI—Economics of Railway Location, for the purpose of determining the necessary reduction in rate of grade through tunnels located on ruling grades to offset reduced haulage capacities of locomotives due to adverse rail conditions. Committee XVI has this matter under consideration but is not yet ready to make a recommendation.

Special Committee on Clearances, as it was found the tunnel section the Roadway Committee desired to use was at two points slightly inside the Clearance Committee's diagram. To enlarge the tunnel section would add considerable to construction cost and not add any useful clearance space. Clearance Committee has made further study and is arranging to recommend a new diagram for tunnels in line with the suggestion of the Roadway Committee.

Committee VIII—Masonry. There seemed to be some overlapping with their Sub-Committee 6, Methods and Practices of Lining and Re-lining Tunnels. There were also some points that the Roadway Committee wished to have considered in the design of masonry lining, such as recesses in long tunnels of sufficient size to hold hand and push cars or a portable air compressor, et cetera, also some drainage matters to clear up.

Committee X—Signals and Interlocking. They were asked to design a system for carrying signal wires through tunnels either in ducts to be installed in the concrete lining or in conduits hung on the wall. Consideration to be given to a signal system that trackmen could use both for passing through or to enable crews that had been working in tunnel with cars set off in recesses to set up protection (provided train is not occupying block) to enable them to come out.

Committee XVIII—Electricity. The question raised with the Committee was also in regard to method of carrying wires through tunnels and in the case of tunnels electrically operated, provision for both lighting and primary circuits as well as hangers for catenary system.

It is also necessary to make provision for telephone and telegraph wires. Neither of these subjects seem to be covered in any A.R.E.A. assignment.

While these wiring problems do not appear to be a part of the assignment of the Roadway Committee, it was thought desirable by this Committee to bring the matter up for consideration. Have acknowledgment from Chairman of Committee X—Signals. He has in turn contacted Chairman of Sub-Committee 6, of Committee VIII—Masonry.

Committees VIII, X and XVIII were each furnished with drawings and information showing actual installation of conduit systems now in use. One layout showed the Cascade Tunnel on the Great Northern Railroad where tunnel is electrically operated and conduits are built in masonry. The other showed treated timber conduit hung on inside of wall of the Vancouver Tunnel of the Canadian Pacific Railway. This is a steam operated tunnel. The liberty was also taken of suggesting that between the various interested committees they might make provision for telephone and telegraph circuits as well. While progress has been made on all the above matters, the only one of the above points yet settled is that of clearances.

BIBLIOGRAPHY

From the many technical publications on tunneling that were reviewed, a general select list has been prepared. There is a complete published index of A.R.E.A. Proceedings covering 1900 to 1915 inclusive. The Proceedings and Manual have been searched for information since that date, and a supplementary index has been prepared of articles in later publications. This index includes items handled under other committees as well as the Roadway Committee, provided items have a bearing on any matter connected with tunnel construction, operation or maintenance. The idea being to provide a complete reference that could be readily consulted by anyone wishing information on any of these points.

Bibliography of technical articles and index of Proceedings are attached as Appendices I–1 and I–2.

TUNNEL CONSTRUCTION

During the past 25 years, three notable railway tunnels have been constructed on the American Continent, and one of special interest in Japan. The special interest of the Tanna Tunnel in Japan is due to the extraordinary adverse conditions encountered during construction and the methods developed to overcome them.

NOTABLE MODERN RAILWAY TUNNELS

Railway	*Tunnel*	*Year Finished*	*Length Miles*	*No. Tracks*	*Ventilation*	*Trains Operated*
Canadian Pacific	Connaught	Nov. 1916	5	2	Fans	Steam
Denver & Salt Lake	Moffat	Feb. 1928	6.3	1	Fans	Steam
Great Northern	Cascade	Jan. 1929	7.79	1	Nil	Electric
Japanese Government	Tanna	Dec. 1934	5	2		

NOTE.—Connaught Tunnel originally known as Rogers Pass Tunnel.

While the first three were speeded up by working from a small Pioneer to one side of main tunnel, and were all very fast pieces of work, the actual methods of construction were quite different and as a matter of fact the methods of attack varied greatly due to different ground conditions in the same tunnel. On the Cascade Tunnel one shaft was put down and work carried from that as well as from either end. The Japanese tunnel was through an earthquake zone. It was all bad ground with some very exceptionally difficult pieces, so no records were made in rapidity of construction.

Connaught Tunnel

Method of construction and timbering is shown on Plate 1. Figs. 1 to 5 inclusive show methods used in ground at east end. Wall plate drifts were first driven. These were then enlarged to take in the whole roof section using a five segment lining. This section was timbered close with 12-in. × 12-in. material. Below the wall plate muck was removed with an air operated shovel, the vertical posts being worked into place as work progressed. On the west end (Fig. 6) the ground was much heavier, making necessary a change in procedure. Crown drift was first driven, then bottom side drifts and top side drifts. Vertical posts were put in place on the completion of the side drifts. The enlargement of the crown drift was then extended to allow for the placing of a seven segment lining. This lining was made up of 12″ × 16″ timbers close together and usually doubled. Fig. 7 shows method in self-supporting rock. Center heading was driven from various points reached by cross cuts from the Pioneer tunnel. Center heading was mucked by hand and disposed of through these cross cuts. Mucking for full section enlargement was done by shovels worked by compressed air.

Moffat Tunnel

Method of construction and timbering is shown on Plate 2. Fig. 1 to 9 inclusive show methods first used at west portal. This is known as the Bench System. A top center heading was first driven and then enlarged to a full top section and timbered with a falsework three segment timber arch of sufficient size to allow the final five segment arch to be placed inside. The bench was then worked down through various stages as shown by Fig. 7, 8 and 9. Removing the bench by this method in the heavy ground proved unsatisfactory on account of the fact that the round was not long enough to fully occupy the shifts during the 24-hour cycle. To devise a method for supporting the wall plates so that a longer round could be taken out, a needle bar support, Fig. 10, was developed. This was later further developed in the machine known as a Lewis Traveling Cantilever. Diagram of this machine and mucking shovel is shown by Fig. 11. Fig. 12 shows the method at east portal in ground requiring support. A center heading was first driven and lined with heavy timber. Overhead rock was then stoked and trapped into cars. After placing timber for the five segment arch, excavation was carried on by hand down to a point eight feet above bottom of tunnel. This bottom eight feet was excavated by ring drilling and shooting. Muck was loaded into cars by a shovel operating on compressed air. Electric mine mucking machines were extensively used in the various heading excavations. In hard rock sections the center heading was enlarged by the ring system of drilling and shooting. Location of holes is shown by Fig. 13.

Cascade Tunnel

Method of construction and timbering are shown on Plate 3. Due to differences in ground encountered various methods of attack were used.

Fig. 1—This method was used where the rock would stand without timbering for a full section of tunnel. This is a center heading enlarged by ring drilling and shooting.

Fig. 2—Center heading followed by a top heading and bench. This was used where ground would not stand for the full tunnel section without timbering.

Fig. 3—Top heading and bench, commonly referred to as the American method. This was also used where it was apparent that the ground would not stand for a full tunnel section without support.

Fig. 4—This is a modification of method shown by Fig. 3 the difference being that the wall plate drifts were first driven.

Fig. 5—This was used in loose material at the west end. A center top heading and wall plate drifts were driven simultaneously, then enlarged to a full top heading and the bench next removed.

Fig. 6—Bottom heading followed by top raises and top center heading, the material from the sides being mucked by shovel. This was used to advantage on account of being able to open up various points on the main tunnel from cross cuts from Pioneer.

Fig. 7—This shows full face method which was used in order to expedite completion by providing additional mechanical loading places to be reached through cross cuts from the Pioneer in advance of main enlargement operations. 1A was shot first and 1B immediately after. The independent round was then drilled and shot when ready.

All mucking in drifts was done by machines. Mucking in enlargements was done by railway type of shovels operated by compressed air.

Tanna Tunnel

Method of construction and timbering is shown on Plate 4. Ground pressures encountered in construction of this tunnel were extraordinarily heavy, necessitating different forms of attack from the generally accepted American types.

Fig. 1 to 4 show procedure in ordinary heavy ground. This sequence of excavation and timbering is known as the new Austrian method. A bottom center heading was first driven, followed by up raises from which a top center heading was driven, muck from the top heading being trapped to cars below and enlargement of the tunnel section followed as per numbering on Fig. 1. In very loose ground where the worst pressures were encountered, the above method could not be used. A different sequence of excavation was necessary. This is shown by Fig. 5 and is known as the German method. The drifts were driven in order of numbers on Fig. 5. These were generally driven about 60 feet in length and as soon as finished immediately filled with concrete pneumatically placed. After hardening, another drift was excavated and filled with concrete. This was repeated until the earth in the tunnel section was completely surrounded by concrete, after which the earth excavated away from the inside. The thickness of the concrete lining in this tunnel varies from a minimum of 2 ft. 4 in. to 6 ft. 3 in.

TUNNEL VENTILATION

The ventilation of the Connaught Tunnel on the Canadian Pacific Railway is provided by duplicate fans driven by Diesel engines blowing air against the tonnage trains.

In the Moffat Tunnel fans are driven by Diesel engines. The arrangement of ducts is such that air can be blown into tunnel or current reversed and air drawn out.

In a tunnel approximately a mile long built at Vancouver in 1932 by the Canadian Pacific Railway, there are duplicate ventilating fans driven by synchronized electric motors. The fans are put automatically into service by a magnetic clutch operated through a track circuit by approaching trains and cut out by a time relay.

There is no artificial ventilation in the Cascade Tunnel.

Conclusions

The above report gives a summary of the investigation carried on by your Committee together with a synopsis of practices adopted in modern railway tunneling.

This is given as information.

It will be noted that modern practice does not in general follow the method approved in Manual of 1929, pages 42, 43 and 44, and there is such a variation necessary even on a single tunnel that it does not appear feasible to recommend any particular practice.

Recommended Revisions of Manual

Present (Bulletin 378, p. 1)	*Proposed*
The forms and dimensions of the clear space provided for single and double track tunnels should be such as to provide clearances established by the Special Committee on Clearances.	The interior dimensions of clear space provided for single and double track tunnels shall not at any point be less than tunnel clearance approved by the A.R.E.A.

Note.—Due to the outline of tunnel sections it may not be desirable to follow the form of clearance diagram, so word "form" should be deleted and "not less than" put in to cover.

Pages 42, 43 and 44—Tunnel Construction. All to be withdrawn.

Note.—Present recommendations have not been followed in modern tunnel construction. Many different methods of procedure have been used and even in a single tunnel several different lines of attack have been used due to development of local conditions.

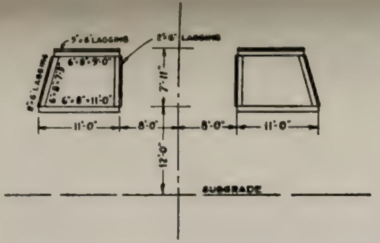


FIG.1 WALL PLATE DRIFT SECTION

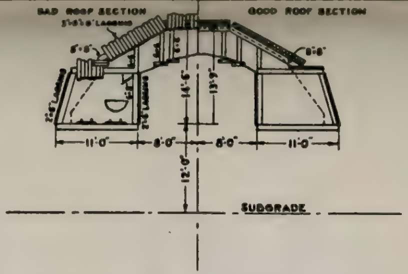


FIG. 2 FALSE TIMBERED HEADING

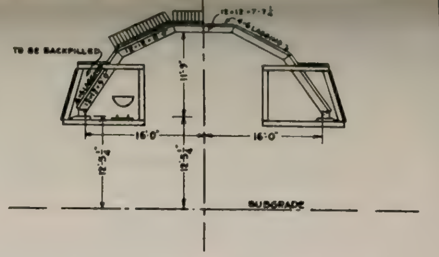


FIG.3 PERMANENT TIMBERED HEADING

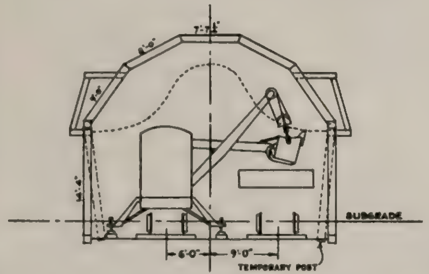


FIG.4 SECTION SHEWING REMOVAL OF BENCH

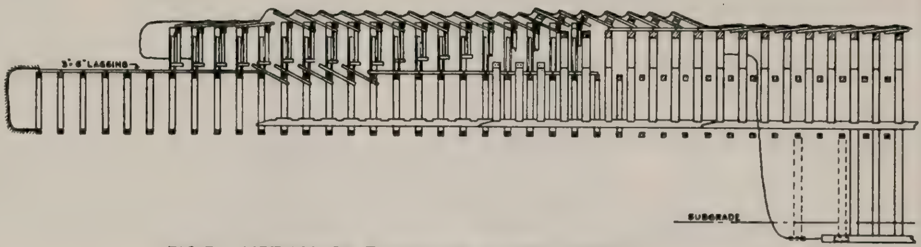


FIG.5 METHOD OF TUNNELING IN SOFT GROUND

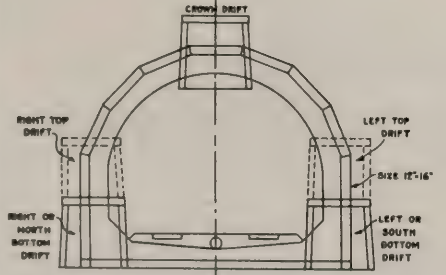
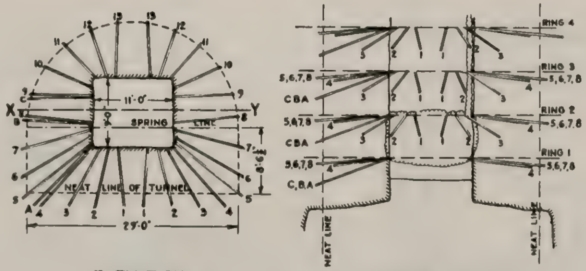


FIG. 6 SEVEN SEGMENT TIMBERING IN WEST END
TIMBERS SET SOLID & USUALLY DOUBLED

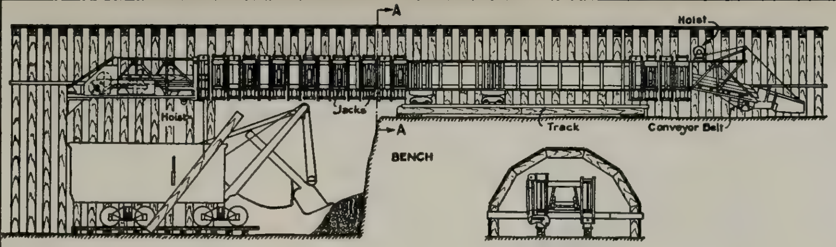


ELEVATION

PLAN BELOW LINE XY

FIG.7 METHOD OF SHOOTING IN ENLARGEMENT

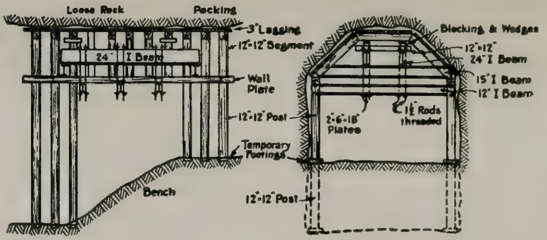
CONNAUGHT TUNNEL
(ROGERS PASS)
CONSTRUCTION METHODS
AREA SUB-COMMITTEE Nº7 - TUNNELS



SECTION A

ELEVATION SHOWING SUPPORT ON BENCH, JACKING UNDER FREE ARCH TO PERMIT UNRESTRICTED MUCKING, AND CONVEYOR SYSTEM

FIG. 11 LEWIS TRAVELING CANTILEVER GIRDER



LONGITUDINAL SECTION

END VIEW

FIG. 10 NEEDLE BARS FOR SUPPORT OF ARCHES

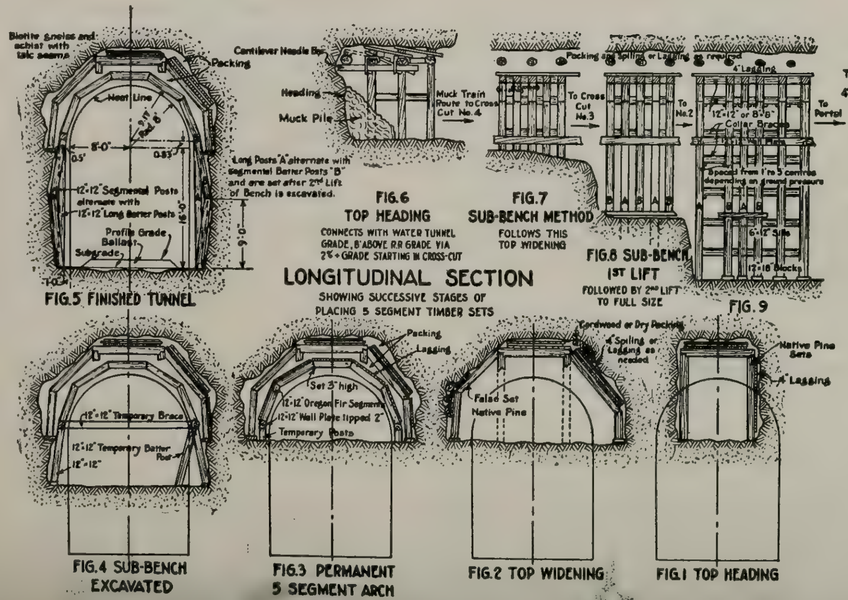

Biotite gneiss and schist with talc seams
Packing
Neat Line
8'-0"
0.5'
0.83'
12"×12" Segmental Posts alternate with 12"×12" Long Batter Posts
Profile Grade
Ballast
Subgrade
16'-0"
9'-0"
1-0
Long Posts "A" alternate with Segmental Batter Posts "B" and are set after 2nd Lift of Bench is excavated.
Cantilever Needle Bar
Heading
Muck Pile
Muck Train Route to Cross Cut No. 4
To Cross Cut No. 3
To No. 2
To Portal
Packing and Spiling or Lagging as required
4" Lagging
12"×12" or 8"×8"
Collar Braces
Spaced from 1' to 5' centres depending on ground pressure
6"×12" Sills
12"×18" Blocks
B A B A B
B A B
12"×12" Temporary Brace
12"×12" Temporary Batter Post
12"×12"
Packing
Lagging
Set 3" high
12"×12" Oregon Fir Segments
12"×12" Wall Plate tipped 2"
Temporary Posts
Cordwood or Dry Packing
4" Spiling or Lagging as needed
False Set Native Pine
Native Pine Sets
4" Lagging

FIG. 5 FINISHED TUNNEL

FIG. 6
TOP HEADING
CONNECTS WITH WATER TUNNEL GRADE, 8' ABOVE R.R. GRADE VIA 2% + GRADE STARTING IN CROSS-CUT

FIG. 7
SUB-BENCH METHOD
FOLLOWS THIS TOP WIDENING

FIG. 8 SUB-BENCH 1ST LIFT
FOLLOWED BY 2ND LIFT TO FULL SIZE

FIG. 9

LONGITUDINAL SECTION
SHOWING SUCCESSIVE STAGES OF PLACING 5 SEGMENT TIMBER SETS

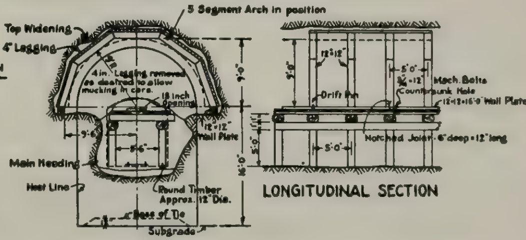
FIG. 4 SUB-BENCH EXCAVATED

FIG. 3 PERMANENT 5 SEGMENT ARCH

FIG. 2 TOP WIDENING

FIG. 1 TOP HEADING

TIMBERING METHOD - WEST PORTAL



VERTICAL SECTION

LONGITUDINAL SECTION

FIG. 12 JUMBO TIMBER SET - EAST PORTAL

FOR TUNNEL ENLARGEMENT IN GROUND REQUIRING SUPPORT

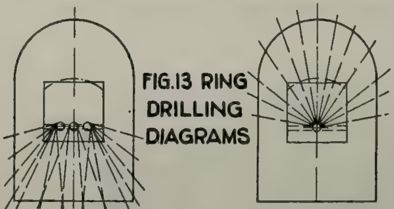


FIG. 13 RING DRILLING DIAGRAMS

MOFFAT TUNNEL
CONSTRUCTION METHODS

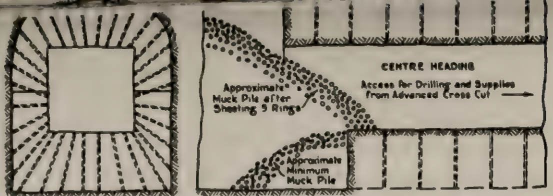

CENTRE HEADING
Access for Drilling and Supplies from Advanced Cross Cut
Approximate Muck Pile after Sheeting 5 Rings
Approximate Minimum Muck Pile

FIG. 1 DIAGRAM SHOWING METHOD OF ENLARGING TO FULL TUNNEL FROM CENTRE HEADING

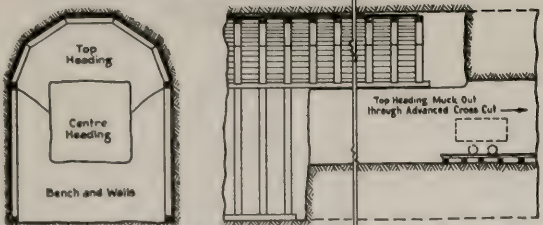


FIG. 2 METHOD OF ENLARGING TO FULL TUNNEL FROM CENTRE HEADING FOLLOWED BY TOP HEADING AND BENCH

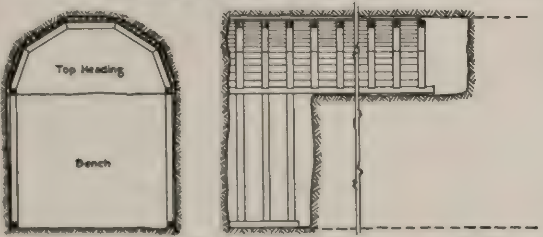


FIG. 3 DIAGRAM SHOWING TOP HEADING AND BENCH METHOD OF DRIVING FULL TUNNEL

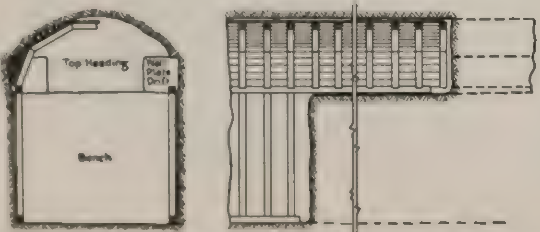


FIG. 4 DIAGRAM SHOWING METHOD OF ENLARGING TO FULL TUNNEL BY MEANS OF WALL PLATE DRIFTS FOLLOWED BY TOP HEADING AND BENCH

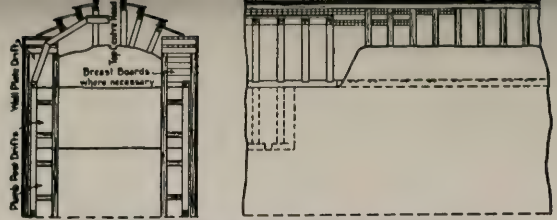
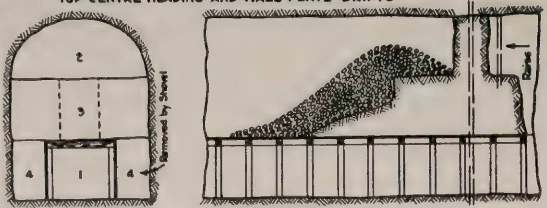


FIG. 5 DIAGRAM SHOWING METHOD OF ENLARGING TO FULL TUNNEL FROM TOP CENTRE HEADING AND WALL PLATE DRIFTS



NOTE Numbers give Sequence of Excavation Operations

FIG. 6 DIAGRAM SHOWING METHOD OF ENLARGING TO FULL TUNNEL FROM BOTTOM CENTRE HEADING BY TOP HEADING AND RAISES

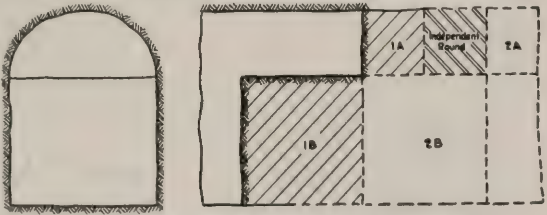
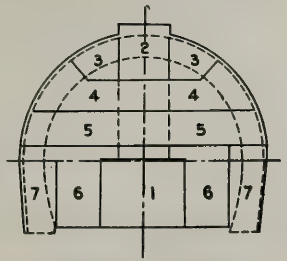
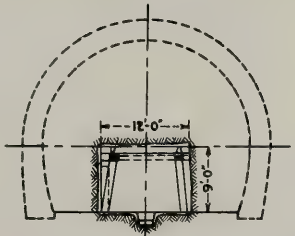


FIG. 7 DIAGRAM SHOWING METHOD OF DRIVING FULL TUNNEL FACE

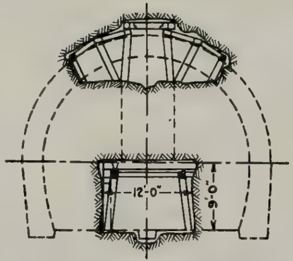
CASCADE TUNNEL
CONSTRUCTION METHODS
AREA SUB-COMMITTEE No 7-TUNNELS



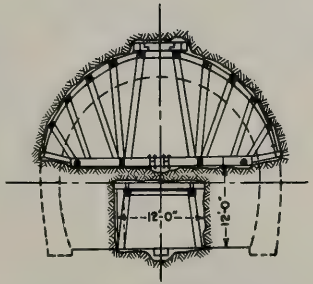
SEQUENCE OF EXCAVATION
ORDINARY EARTH
FIG. 1



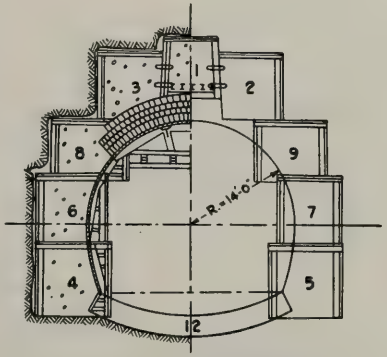
FIRST STAGE OF EXCAVATION
ORDINARY EARTH
FIG. 2



THIRD STAGE OF EXCAVATION
ORDINARY EARTH
FIG. 3



FIFTH STAGE OF EXCAVATION
ORDINARY EARTH
FIG. 4



SEQUENCE OF EXCAVATION
LOOSE GROUND
FIG. 5

TANNA TUNNEL
CONSTRUCTION METHODS
AREA SUB-COMMITTEE No. 7 - TUNNELS

Appendix I–1

BIBLIOGRAPHY OF ARTICLES ON TUNNELING METHODS AND TUNNELS

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Can. Engr., Vol. 29, No. 9, Aug. 26, 1915, pp. 293–296.

"Completing the Mount Royal Tunnel into Montreal"
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Chas. S. Churchill, Railway Review, Oct. 30, 1915.

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Appendix I–2

Index of articles in A.R.E.A. publications that have a relation to tunnel construction or maintenance covering period from January 1916 to August 1935.

For articles previously published see A.R.E.A. index 1900 to 1915 inclusive.

	Year		Vol.		Page	Subject
Proceedings	1926	Vol.	27	Page	784	Tunnel sections.
"	1930	"	31	"	590	Corrosion of rail and fastenings in tunnels.
"	1931	"	32	"	159	Corrosion of rail and fastenings in tunnels.
"	1932	"	33	"	653	Prevailing practices for lining and relining tunnels.
"	1934	"	35	"	979	Tentative specifications for lining and relining tunnels.
"	1935	"	36	"	304	Revision of Manual.
"	1935	"	36	"	863	Methods of lining and relining tunnels.

Appendix J

(9) SIGNS

J. A. Noble, Chairman, Sub-Committee; F. W. Alexander, G. H. Burnette, L. J. Drumeller, E. R. Lewis, P. T. Simons, E. M. Smith.

An inquiry sent to fifty American Railroads requesting information concerning their standard roadway signs disclosed that none of these railroads were using the designs shown in the Manual for all of their corresponding signs. The following statement shows the situation:

Number of Railroads Canvassed	*Number of A.R.E.A. Signs Used*
1	9
1	7
1	5
4	4
2	3
3	2
10	1
28	None

In view of this information, the Committee recommends that the existing material regarding Roadway Signs in the Manual, pages 77 to 88 inclusive, be deleted therefrom, and that the subject be continued for further study.

REPORT OF COMMITTEE XXVII—MAINTENANCE OF WAY WORK EQUIPMENT

C. R. Knowles, *Chairman;*
W. A. Batey,
G. E. Boyd,
Walter Constance,
W. O. Cudworth,
J. J. Davis,
J. T. Derrig,
J. F. Donovan,
C. R. Edwards,
William Elmer,
G. J. Ermentrout,
Robert Faries,
C. L. Fero,
Paul Hamilton,
R. C. Haynes,
F. S. Hewes,
F. W. Hillman,
L. B. Holt,
Harry Homans,
C. H. R. Howe,
J. S. Huntoon,
E. A. Johnson,
Jack Largent,
E. H. Mills,
R. A. Morrison,
C. H. Morse,
E. H. Ness,
G. R. Westcott, *Vice-Chairman;*
C. H. Ordas,
E. Pharand,
T. M. Pittman,
J. C. Ryan,
J. G. Sheldrick,
H. E. Stansbury,
N. M. Trapnell,
J. M. Trissal,
L. J. Turner,
R. P. Winton,
Fred Zavatkay,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual (Appendix A).

(2) Standardization of parts and accessories for railway maintenance motor cars (Appendix B). Presented as information with recommendation that study be continued.

(3) Track Grinders (Appendix C). Complete and presented as information. Recommend subject be discontinued for present.

(4) Electric Tie Tampers. Progress in study—No report.

(5) Use and adaptability of crawler-type tractors in maintenance of way work. Progress in study—No report.

(6) Methods of keeping data on work equipment—No report. Recommend subject be discontinued for present.

(7) Selection and training of maintainers and operators of work equipment (Appendix D). Complete and presented as information. Recommend that subject be discontinued.

(8) Concrete mixers and concrete handling machinery (Appendix E). Complete and presented as information. Recommend subject be discontinued.

(9) Machines for laying rail and their auxiliary equipment. Progress in study—No report.

(10) Track welding equipment (a) oxy-acetylene; (b) electric arc. Progress in study—No report.

(11) Manual of instructions for care and operation of maintenance of way equipment (Appendix F). Complete and presented as information. Recommend study be discontinued.

(12) Power bolt tighteners. Progress in study—No report.

(13) Power saws. Progress in study—No report.

The Committee on Maintenance of Way Work Equipment,
C. R. Knowles, *Chairman.*

Bulletin 381, November, 1935.

Appendix A

(1) REVISION OF MANUAL

C. R. Knowles, Chairman, Sub-Committee; G. E. Boyd, Walter Constance, Harry Homans, J. S. Huntoon, C. H. Morse, G. R. Westcott.

The following revisions of material now in the Manual and Supplements thereto are recommended by the Committee:

(1) The elimination of the following definitions appearing on pages 113 to 122, Vol. 33, Bul. 337, July 1931, revisions and additions to the Manual:

Axle
Ballast Car
Ballast Tamping
Battery
Boom
Box, Battery
Camp Car
Canvas
Car, Hand
Car, Motor
Car, Outfit
Car, Section
Car, Inspection
Carriage Bolt
Cell
Cell, Dry
Clam-Shell
Convertible Car
Crane
Deck, Seat
Derrick Car
Derrick, Crane
Ditcher
Ditcher
Dolly, Track
Drag Line Bucket
Drill, Bonding
Drill
Drill, Flat
Drill, Pneumatic
Drill, Rock
Drill, Rotary Hand
Drill, Track
Drill, Twist
Drop Hammer
Dump Car
Excavator, Drag Line
Flange
Flywheel
Free Air
Gage of Track
Gearing
Gear
Ground Wire
Grounded Parts
Hammer, (Pile)
Hammer, Pneumatic
Hoisting Drum
Hoisting Engine
Hose
Hose Clamp
Journal
Knife Switch
Leads, Pile Driver
Lock Nut
Lubrication
Lubricator
Nutlock
Orange Peel Bucket
Pile Driver
Pinion
Pulley
Saws
Scraper Dump
Spark Coil
Spark Plug
Split Key
Spreader
Steam Hammer
Steam Shovel
Tackle Block
Thumb Screw
Velocipede Car
Volt
Volt Meter

(2) By agreement with Committee XXII the following material now appearing in the 1929 Manual has been turned over to Committee XXVII, and with the exception of certain deletions and revisions will be included in the Manual chapter of Committee XXVII:

(a) That material relating to methods of maintaining motor cars, together with Exhibit 2, appearing on pages 1467–8–9 of the 1929 Manual.

(b) The drawings of the standard axle and of the standard wheel tread and flange for 16-inch and 20-inch wheels of maintenance motor cars, appearing on pages 87–88 of the 1930 Supplement to the Manual.

(3) It is recommended that Exhibits 2 and 4 facing page 1468, 1929 Manual be omitted.

(4) It is recommended that Paragraphs 1, 2 and 3 relative to Economics of Brush versus Spray Painting, Vol. 33, p. 402, 1932, revisions and additions of Manual, Bulletin 347, page 70, be omitted.

Appendix B

(2) STANDARDIZATION OF PARTS AND ACCESSORIES FOR RAILWAY MAINTENANCE MOTOR CARS

G. R. Westcott, Chairman, Sub-Committee; G. J. Ermentrout, Paul Hamilton, R. C. Haynes, Jack Largent, E. H. Ness, C. H. Ordas, J. G. Sheldrick, L. J. Turner, R. P. Winton.

Your Committee's study this year has centered mainly around the standardization of wheels and axles. Fig. 1 and 2, pages 87 and 88, Bulletin 327, Supplement to Manual of 1929, are incomplete in many details and as now existing do not definitely provide for interchangeability of parts, which is understood to be the aim of the work under this assignment.

Below is a brief discussion of some of the questions under consideration:

(A) Contour of Wheel Flange and Tread

This involves setting out, with appropriate tolerances for manufacture, the desirable contour of flange and slope of tread.

Experience in operation of motor cars has indicated that a wheel tread flatter than the AAR standard of 1 in. in 20 in. has less tendency to cause whipping or nosing of the car.

It should be kept in mind that in several particulars the conditions in connection with motor cars differ from those affecting train equipment. Some of these which may be directly involved in whipping are:

(a) Absence of the stabilizing effects inherent in the car itself of weight of car, length of wheel base and difference in diameter of wheels.

(b) Lack of stabilizing influence exerted by the preceding car which is very great in a train but entirely absent in a self-propelled motor car.

Recent experiments on the Chicago, North Shore and Milwaukee which demonstrated that excessive nosing of trucks at high speeds could be corrected by making the wheel tread flat, are interesting in this connection but not applicable to motor cars since the serious nosing of the electric car trucks did not occur until a speed of 60 miles per hour was reached.

It is recognized that from the standpoint of manufacture a flat tread is impracticable but a tread having a slope of 1 in. in 50 in. is entirely feasible.

(B) Tolerances in Diameter of Wheels

For interchangeability it is exceedingly desirable that actual diameter of wheels be kept within very close limits. To date, your Committee has not been able to agree with the manufacturers on what the tolerances should be.

(C) Length of Axles

Again for interchangeability it is necessary that the effective length of axles be held to close limits, and that taper on the ends be uniform. A means of readily checking these features is being developed.

(D) Thickness of Insulation

Fig. 1, page 87, Bulletin 327, Supplement to Manual of 1929, shows insulation thickness of ⅛ inch. There has been some thought that this is thicker than necessary. However, the important feature in the view of your Committee is that a uniform practice be established. ⅛ inch insulation has been more widely used in the past than any other size and to continue its use will probably lead to less confusion than the adoption of any other size.

On all of the above matters your Committee is in general agreement. However, since they involve considerations affecting the manufacturers, it does not seem wise to present revised plans to the AREA until the manufacturers' views have been received and considered.

Your Committee also feels that there are certain features of motor car design on which no recommendation of standard practice can be made but which are of sufficient general interest to warrant a brief discussion. Among those are steel wheel construction and steel frame construction. Until recent years the usual type of wheel for section duty motor cars was a cast or forged steel or malleable iron hub on which was mounted by means of rivets a disc and rim of rolled steel plate.

Malleable iron, forged steel and cast steel are all used for the making of hubs. Forged steel having greater tensile strength than malleable iron is claimed to resist better in mounting the wheels any tendency to drawing them too far on the axle resulting in under gage. However, malleable iron has proven very satisfactory. Cast steel is less used.

Both 16-inch and 20-inch wheels are used. For cars of about 1200 lb. weight 20-inch wheels are usually of ¼-inch plate as the use of heavier plate would unduly increase the weight of the car. For heavier gang cars 5/16-inch plate is used.

For 16-inch wheels, 5/16-inch plate has been found more satisfactory due to longer life. Having a 20 per cent greater contact with the rail in traveling a given distance, the 16-inch wheel where used wears out much more rapidly than the 20-inch wheel, and 16-inch wheels where made of ¼-inch plate were found to be of comparatively short life.

Both cold and hot forming of the plates have their adherents. Both have proven satisfactory in use.

In the riveting of the plate to the hub, practice has varied considerably. In some cases six rivets per wheel are used, in others eight. Recent wheel failures on 20-inch wheels have raised a question as to whether six rivets are sufficient for that size of wheel. Hot and cold riveting have both had their adherents also, but there is no conclusive data that either is markedly superior to the other.

While the practice of assembling the plate and hub in such a manner that the rivet is not thrown into tension by the thrust of the wheel flange against the rail is theoretically to be preferred, actual results cannot be said to prove the necessity of this method.

Recently there is some tendency to abandon the riveted wheel, two substitutes being proposed. They are: (1) welding the steel plate to a cast steel hub. At the present time this may be said to be in the experimental stage. Time and experience will develop whether or not it is advantageous; (2) the demountable type of wheel in which bolts instead of rivets are used. Although the initial cost is somewhat higher than for riveted wheels, there are some decided advantages:

(a) The tire alone can be renewed in the field if desirable; and as wheel wear is mainly in the tire, this will tend to offset the higher initial cost when price of the tire alone is properly adjusted in comparison with the cost of the entire wheel of riveted type.

(b) The renewal of the tire does not disturb the insulation nor the gage of the wheels, and use of wheel puller is not needed in changing tires.

(c) As the same hub is used for different sizes of wheels, the number of parts required to be kept in stock is reduced.

On the other hand, care must be used in applying new tires to see that the bolts are drawn up in such a way that the tire and hub are in proper relative position. When properly assembled in the type of wheel now available the vertical thrust is carried directly from the hub to the tire and is not carried by the bolts. Stated otherwise, the bolts are in tension only and not in shear.

The demountable wheel may be said to have passed the experimental stage; thousands of these wheels are now in satisfactory service.

Without entering into any discussion of the relative merits of wood and steel frame construction, both having their place in different types of cars, a short discussion of steel frame construction is in order.

For years steel frames, except those made by one manufacturer, were of structural members riveted together. Experience in the field has shown this not entirely satisfactory, mainly from the fact that rivets would, through vibration, work loose. In the way of repairs, welding was resorted to on many railroads, the remedy proving worse than the weakness which it was designed to correct. Apparently there must be in the frame a certain amount of resiliency which the welded joint did not have, and failure of the members, usually in the vicinity of the weld, resulted.

Out of this observation came the suggestion that in lieu of rivets, bolts of heat treated steel having SAE threads should be used. Although not proven by long use, this method is very promising, and seems to combine adequate strength and durability with sufficient resiliency to prevent fracture of the frame members.

For old riveted frames on which rivets are loose, the replacing of rivets with heat treated bolts is the best suggestion that can now be made.

Your Committee recommends that this report be received as information and the subject continued for further study.

Appendix C

(3) TRACK GRINDERS

Robert Faries, Chairman, Sub-Committee; Walter Constance, William Elmer, L. B. Holt, E. A. Johnson, E. H. Mills, J. C. Ryan, L. J. Turner, R. P. Winton.

In our report for 1934 (Proceedings, Vol. 35, pp. 475–82) we classified grinding machines into three groups: (A) Rail Surface Grinders; (B) Side-flow Grinders; (C) Cross Grinders. The Rail Surface Grinders were sub-divided into two classes (1) those using revolving wheels, and (2) machines of the reciprocating type, where the grinding blocks are moved back and forth along the surface of the rail head.

Rail surface grinders using revolving wheels are separated into (a) those grinding on the edge of a wheel usually 10 in. to 14 in. in diameter and 1 in. to 2 in. face, and (b) those using the flat face of a cup wheel.

The earliest of the Type A-1-a grinders consisted of an air or electric motor with a wheel about 6 in. or 8 in. in diameter, mounted on the spindle, the machine being held in the hands of the workman, and the circumference of the wheel being pressed against the metal to be removed. Needless to say, there was no pretension to accuracy of surface in the performance of this grinder, but it did provide a tool which had previously been lacking.

One drawback to the electric grinders was the frequent lack of an available source of current at the site of the work, and the fact that AC motors could not be used on DC current, and vice versa. This latter difficulty was later overcome by the development of a universal motor which could be used on either AC or DC current, although these motors are of inherently small horsepower. However, it is not possible for a workman to hold a grinder in his hands and absorb more than about one-half HP on any grinding done on railroad rails, frogs, or switches. This means a very slow and costly performance where any considerable amount of metal is to be removed.

In an effort to secure a machine which could be used anywhere in the field without setting up an air compressor, or being tied to a source of current, the Stow Manufacturing Company produced a machine powered with a Briggs & Stratton engine of 3 to 4 HP with a direct coupled flexible shaft, carrying at the end a spindle with handles and guard, the whole outfit being portable and carried by two men. It was soon found that the whip imparted to the flexible shaft on starting or stopping the engine resulted in frequent breakages, the condition being aggravated by the flywheel effect of the grinding wheel. So a countershaft was introduced with "V" belt drive, the shaft being cam mounted so the tension of the belts could be released when starting or stopping the engine.

The next development of the above idea was by the Nordberg Manufacturing Company. Their machine was provided with dolly wheels to run on one rail, with an extension arm and roller to bear on the other rail and keep it upright. Circular steel hoops surrounded the engine so it could be rolled off the track on the approach of a train. The operator could tow the machine along the track by the flexible shaft and the joints ground first on one rail and then on the other.

In the meantime, the Railway Trackwork Company had been building for many years several types of grinders for electric railways, powered with 500 volt DC motors, taking current through a pole hooked over the trolley wire and rolled off the track on to the pavement to let a car by. These grinders were used to finish the surfaces of battered rail ends built up by electric welding, and after the steam roads adopted this process the same type of machine was used by the Teleweld Company, and the Railway Trackwork Company brought out their gasoline engine driven grinders. These have the wheel supported in the frame of the machine with the spindle at right angles to the rail and movable axially across the rail head, while the whole machine rolls back and forth on the rails, being moved by the hand of the workman. The grinding wheel is fed downward on the rail head by means of a handwheel and feed screw. These machines are in general use, usually being powered by a gasoline engine, with speed regulation to permit of maintaining a practically constant peripheral speed of the grinding wheel until it is nearly worn out. This speed adjustment must be closely watched, however, as a grinding wheel designed to do the best work at a cutting speed of 9500 ft. per minute may suffer a loss of efficiency as much as 75 per cent if the rpm are allowed to fall too low. There is one disadvantage in regulating the speed of the gasoline engine, however, as the horsepower output is almost directly proportional to the rpm. Consequently, when a new wheel is placed on the spindle, the speed of the engine must be slowed down in order not to risk bursting the wheel. This results in the lowest horsepower output of the engine when it would be desirable to have it the highest. (New wheel, large heat radiating surface, etc.) Then as the wheel wears down, the engine speed must be increased in order to keep the wheel cutting efficiently and, consequently, the horsepower is greatly augmented. As the wheel nears the minimum diameter the horsepower available may be in excess of what the wheel can absorb.

In the early machines of this type the power plant was usually a single cylinder Briggs & Stratton engine, which delivered about four HP at its highest speed. More modern machines are using multi-cylinder engines of higher horsepower.

There are several fundamental disadvantages, however, in this type of grinder. As the whole machine rolls back and forth on the rails, any irregularities in the surface of the rail head will be reproduced at the joint being ground. If the track wheels are out of round, or if dirt accumulates on the tread, the contact point of the grinding wheel with the rail head will rise and fall, and it will be impossible to obtain a true surface. There is also a mechanical difficulty which heretofore has not had the attention given to it which its importance warrants. The grinding wheel is fed downwards against the head of the rail being ground by means of a handwheel and screw. There is bound to be a free fit between the screw and the nut which embraces it, and this means lost motion which again means irregularities in the finished surface. It would seem to be possible to devise an arrangement of tension springs so as to keep the nut always pulled up against the lower surfaces of the screw thread, so that in backing up the screw, the wheel would immediately rise. But there must be some freedom of fit between the spindle and its bearings, even if it is only 2 or 3 thousandths of an inch when the machine is new and, of course, in a relatively short time this play will increase. The cumulative result of all these small amounts is that the average lost motion in grinders of this type by the middle of the season will be anywhere from 10 or 15 thousandths up. Another source of error in the ground surface is caused by the wandering of the machine from side to side as it rolls back and forth on the rails. The curve of the top of the rail head cannot be accurately reproduced and it is very difficult to form a satisfactory runoff.

In view of these manifest defects, efforts have been made in recent years to overcome some of them and several manufacturers have developed so-called Precision Grinders. The under-carriage is similar to the arrangement above described, but instead of the machine rolling back and forth on the rails, it is anchored to the track by applying a brake to the wheels and the grinding wheel is carried by a crosshead which slides on guides. Consequently, wheels out of round or irregularities of rail head surface do not influence the position of the grinding wheel. This is a step forward, but guides and slides wear and the lost motion in the feed screw and wheel spindle still remain and the term "Precision Grinder" is somewhat of a misnomer.

A regrettable feature of the machines described above is the fact that they are large and heavy, and in order to have sufficient power to do their work rapidly, they must have strength and rigidity and be equipped with a 10 or 15 HP gasoline engine. This means that they cannot be readily removed from the track, and consequently permission to occupy the track must be obtained from the dispatcher. In multiple track territory this is a serious disadvantage, and a large gang of men must be available to carry the machine off to one side. The Railway Trackwork Company have developed a machine, in which the grinding wheel is driven by a 3 to 5 HP electric motor by "V" belts and most of the weight is concentrated over the rail being ground. It is a one-sided grinder, with an outrigger reaching to the other rail to keep the machine upright. This outrigger may be detached by unlocking a cam and the machine may be set in the intertrack space to permit the passage of trains. It has the disadvantage, however, of requiring a source of power outside itself, being usually operated from a generator driven by the main welding generator engine. This is not entirely desirable as the welding and grinding operations are absolutely tied together, and any failure of the grinder means that the welders may have to stop until repairs are made, or vice versa. Furthermore, there are cables to handle. The limited power is also a drawback, but the greatest objection has been with fixed speed motors; which results in a great loss in efficiency as the wheel wears down. Where electric grinders driven by the main power plant are used they should be equipped with variable speed motors.

A modification of the type A–1–a machine is the Fox grinder, in which a spool shaped wheel, 6 in. in diameter and 8 in. long is carried on a 2⅜ in. spindle set at an angle of 32 degrees to the rail. The machine is carried on two wheels with an outrigger arm to the opposite rail and is powered with a 5 HP gas engine. The grinding wheel is driven by a "V" belt and is carried in a frame which slides back and forth on pipe guides, the machine being locked to the track. The curve of the rail head is reproduced quite well, and the machine may be removed from the track by one man by using a derailing device and the outrigger arm folded around so as to keep the machine within clearance limits when it is standing in the intertrack space and permit the passage of trains.

The rail head surface obtained with the Fox grinder is very satisfactory, as on account of the angular position of the spindle the wheel does not leave one rail head at a joint until it is in contact with the other. Consequently, the two top surfaces of the abutting rail heads are absolutely in the same plane. This machine has been used quite extensively to smooth up joints which have been battered from 10 to 20 thousandths of an inch and which are not yet bad enough to warrant building up by gas or electric welding. It is also useful following the laying of new or cropped rail, grinding the adjoining ends so that they are the same height.

Another development is the use of the Fox grinder for corrugated rail. More will be said on this subject later, but it may be mentioned in passing that this is the only machine of Type A–1–a which has been used for this purpose. A battery of four machines is moved slowly along the rail to be ground, one after the other, each taking off from 2 to 3 thousandths of an inch from the top of the high spots. After the passage of the fourth machine the corrugations are removed, if not over 8 or 9 thousandths deep.

We now come to the Class A–1–b grinders—those using the flat face of a cup wheel. The first machine using this principle was exhibited at the National Railway Appliance Show in 1930. It consisted of a pair of posts clamped to the rail head by a cam locking lever, the posts standing about 3 ft. apart, and tied together at their tops by a pair of steel tubes, ground and polished. These served as guides to carry a crosshead sliding back and forth, the crosshead supporting a vertical spindle with a cup wheel at its lower end. The spindle housing was in trunnions so the wheel could be rocked slightly across the rail head in order to reproduce the radius of the head. This was designed by the Mall Tool Company, and the wheel was driven by a flexible shaft from a portable gasoline engine placed on the track near the joint to be ground. The ends of the tubular guides were adjustable up and down, so as to position them parallel to the rail heads. The cup wheel was fed downward by a feed screw and hand wheel, but the difficulty of lost motion in the spindle bearings, feed screw nut, trunnions and crosshead, as mentioned above, proved too difficult to overcome, and the machine was never put in production. Later on the Railway Trackwork Company designed a modification of their P–8 grinder, using a conical shaped cup wheel, but it was not a success and only one was built.

However, the Mall Tool Company continued to study the problem and brought out their angle spindle with an 8 in. cup wheel, driven by a flexible shaft. The source of power was a Briggs & Stratton gasoline engine, with "V" belt drive to a countershaft to which the flexible shaft was connected. By making the driving pulley on the engine and the driven pulley on the countershaft in the ratio of 5 to 3, the engine can run at a reasonable speed, say, 1800 rpm, thus insuring longer life and less frequent repairs. One advantage of a cup wheel is that it runs at a constant speed and when the governor of the engine is once set to give the proper speed of 8500 ft. per min. peripheral speed to the wheel there is no necessity to change it as the wheel wears down. A wheel 8 in. outside diameter and 3 in. inside diameter, and 1½ in. thick is built up on a steel back with dovetail grooves and a raised boss in the center tapped to fit the thread on the angle spindle. Thus the abrasive material of the wheel can be entirely used up and the backs returned to the factory to be refilled. A circular guard is thread mounted on the spindle housing so it may be raised up as the wheel wears away.

There are various mountings for this grinder, one having the engine centered over one rail with light detachable axles extending to the opposite rail so the machine may be lifted off the track and placed between tracks on multiple track systems to permit the passage of trains. But, as this arrangement occupies the track, a wheelbarrow mounting has been developed in which a 20 in. × 3 in. pneumatic tired wheel is placed at one end and the machine can be rolled along between tracks or on the shoulder without the necessity of asking the dispatcher for the use of the track. In busy multiple track territory this insures more actual grinding time per day, and the cylinders of the largest engines will clear the machine even where tracks are 12′ 2″ centers.

The cup wheel with angle spindle on the end of a flexible shaft frankly abandons all the preconceived ideas which were embodied in so-called "precision grinders". As a matter of fact it has the ability to accomplish the desired end—namely, to grind a finished surface, true to a straightedge, with an error of 0.002-inch or less. Wear in the spindle bearings or lost motion in any of the parts has no effect on the accuracy of the work, and the machine will do as satisfactory a job at the end of the season as it will when it is brand new. This comes about because the workman is trained to grind to his straightedge and when he notes where the high spots are and grinds off the high spots he will obtain a true surface in the minimum time and with any allowable error previously decided on. It takes time to grind a rail joint to the straightedge with an error of not over 0.005-inch and with a proper runoff at a slope of not over 3 or 4 thousandths of an inch per inch, but it can be done with the cup wheel and flexible shaft and equally good results obtained day after day and month after month. The Railway Trackwork Company and the Nordberg Manufacturing Company also make these wheelbarrow type grinders and quite a number are now in use in various parts of the country.

We now come to the Class A–2 rail surface grinders, the reciprocating type, where the grinding blocks are moved back and forth along the rail head. Here, again, the Railway Trackwork Company were pioneers, having had a large amount of experience in the street railway field. For some reason, not clearly evident, the electric street railways have been troubled for many years with corrugated rail, and the reciprocating grinder was designed to remove the corrugations. It is usually a heavy, powerful machine, operated by 500-volt motors supplied with current from the trolley wire. The grinding blocks are clamped in a frame or crosshead, sliding back and forth on guides by a connecting rod from a crank shaft, and fed downward as they wear by a handwheel and feedscrew. The machine is moved along the track a few inches at a time and the blocks reciprocated back and forth until the corrugations disappear. It is a slow process, because the cutting speed of the abrasive blocks is low, but it is effective and certainly much cheaper than taking out the rail.

Up until quite recently, the steam roads have not been seriously troubled with corrugated rail, but it has finally made its appearance and at some locations causes continuous maintenance expense to keep satisfactory line and surface. The Railway Trackwork Company have developed two types of grinders for steam road use. One is a heavy double sided machine with a Ford power plant. This occupies the track and must be run to a siding to clear. The Ford engine propels the car as well as furnishing power to operate the crank shaft. The connecting rod moves the crosshead back and forth with a stroke of 3¼ in. at 200 rpm. The grinding blocks are 3½ × 4 in. and 10 in. long, and they soon take the shape of the rail head and form a practically perfect surface.

This machine has also been used for truing up the surface at joints where the batter is not over 10 to 20 thousandths of an inch. It is also used to grind newly laid rail or cropped rail to bring the surfaces of the abutting ends to the same plane.

The other grinder made by this company is a lighter machine designed to operate on one rail, and it can be lifted off the track and placed between tracks to permit the passage of trains. It is powered by a Briggs & Stratton gasoline engine and, of course, takes more time to grind a joint than the more powerful double sided machine. However, it usually gets in more actual working hours grinding in the course of the day, and as the interest, depreciation and repair charges are much less there is little difference in the cost per joint.

While discussing corrugated rail grinding, mention should be made of a large grinding car built by the Lehigh Valley Railroad. It consists of a heavy tank car, mounted on special four wheel trucks, with axles 10-ft. centers, so as to provide room between the wheels for groups of grinding blocks, pressed down on the rails with air cylinders. It is run back and forth over the track at 40 mph by a locomotive. A stretch of track about 5 miles is taken and worked over until the corrugations are ground out, water being supplied to the blocks while they are in action. A full description of this unit appears in the Railway Age for September 1, 1934.

The next classification of Track Grinders is Group B—Side Flow Grinders. The railroads have been put to heavy expense for many years changing out stock rails at switch points. The cold rolling of the rail head under traffic forces the metal out sidewise and forms a bead which prevents the switch point from closing up tight against the stock rail. The result is chipped points and possible derailments. Probably the first use of the air and electric grinders previously mentioned was to remove this overflow. But it was using a wheel in a bad manner, and the finished job was poor at best. The cup wheel offered the solution, but the early method of fastening the wheel by a nut on the end of the spindle made it impossible to use up the wheel clear to the back. One machine was built using a Chicago Pneumatic Tool Company's Hi-cycle motor carried in a 3-wheel frame, two wheels on 3-ft. centers bearing on the rail to be ground, and the third wheel resting on the opposite rail. By using 9 in. diameter cup wheels, the spindle and nut were raised above the level of the rail head, and the frame kept the machine square with the rail in both the horizontal and vertical planes. But the Hi-cyle portable power plant at a reasonable price was not available and the machine was never put in production.

Shortly after, the Ingersoll–Rand Company brought out a stock rail grinder powered with an air motor and operated by pushing it back and forth like a lawn mower, the cup wheel being pressed against the rail head by a roller on the opposite side of the rail head, pressure being exerted by a lever under the hand of the operator. Then the Railway Trackwork Company designed their P–16 machine with its own gasoline engine drive. Several manufacturers have devised cup wheel attachments for flexible shafts for stock rail grinding, dressing up switch points, etc., and these are doing very satisfactory work and saving large sums of money every year.

The third classification of Track Grinders is Group C—Cross Grinders. The earliest method of forming a V-notch where rail ends butted together in a joint was by means of a triangular file in the hands of a workman. This was slow and costly, and a machine was gotten up to drive a parting tool across the rail ends, the operator working a lever back and forth. But cutting hard cold-rolled rail ends is a difficult job for even the best tool steel. The advent of the Bakelite bond and the progress in the wheel maker's art had produced the thin high speed wheels used in cutting-off machines, and when 6 in. or 8 in. in diameter and ⅛-inch thick could be operated at a peripheral speed of 16,000 ft. per minute. A light 4-wheel carriage to run on the rails, with handles at each end, formed the chassis. It could be set off between tracks to allow trains to pass. The axles were light tubing supporting a frame on which was mounted a gasoline engine belted to the wheel spindles. The frame could be moved to one end of the chassis and the rails on that side V'd, and then the machine pushed along the track and the joint in the opposite rail ground. The work was fast and cheap, the average output being about a joint a minute.

Several makers then got up attachments for their flexible shaft outfits, where a frame was clamped to the rail and the thin wheel operated across the joint by hand. The Keystone Grinder Company later brought out a multiple spindle machine with 2 or 3 different thicknesses of wheels at each end for joints tight, slightly open, or wide apart. The Northwestern Motor Company then designed their precision machine and the Railway Trackwork Company brought out their P–11. The ⅛-inch wheel can cut straight down on the end of a rail even if the joint is open to any amount.

One of the Eastern roads has developed a self-contained geared portable grinder having a Universal electric motor which can be used on 110 volts DC or 25 to 60 cycle AC where power is available at towers or signal circuits or from welding generators. These machines are very satisfactory for grinding crossings, frogs, switches and stock rails. Due to the fact that the motors run at over 10,000 rpm a continuous output of ½ HP and a maximum output of ⅞ HP for short periods can be obtained from a complete grinder weighing less than 25 lb. These grinders are much lighter and easier to handle and require much less maintenance than flexible shafts with standard speed electric motors. These grinders can be equipped with automatic overload circuit breakers which will trip out if the normal rating is exceeded continuously, but will permit considerable overload for short periods. In case the circuit breaker trips out from too much load it can be reset as soon as the motor cools down. This permits the maximum production without danger of burning out the motor. With a standard spindle speed of 3300 rpm vitrified wheels with a maximum diameter of 6 in. can be used but Bakelite bonded wheels with a maximum diameter of 8 in. are more satisfactory.

WHEEL SPECIFICATIONS

It has been suggested that this Committee prepare specifications for grinding wheels. We believe this is a very difficult, if not impossible task. While almost any kind of a wheel may be made suitable for grinding almost any kind of material, the fact remains that very few of the ingredients or processes are standardized. In the early days, when all grinding was done with emery wheels, it would not have been so hard to prepare a specification. Or even a few years ago, when silicate or other forms of vitrified inorganic bonds were the only ones available. But now we have Bakelite, rubber, shellac and other organic bonds and we could not specify one without shutting out something equally as good or better.

There is one item, however, that has been standardized and that is the size of the grit or grain. The National Bureau of Standards has prepared specifications for standard screens with various numbers of meshes per inch, and these are in universal use by all manufacturers of grinding wheels. "Abrasive Grain Sizes" Simplified Practice Recommendation R 118–30 may be obtained from the Superintendent of Documents, Washington, D. C., for 5 cents. A very coarse grain, such as No. 10, means that these grains will pass through a sieve with 10 meshes to the linear inch (100 per square inch) and be retained on a screen with 12 meshes to the inch. The sizes do not increase by units but run Nos. 12, 14, 16, 20, 24, 30 and 36. The still finer sizes run up to 600, but these are of no interest to us for use in rail grinders. It is likely that our work will use grain sizes falling between Nos. 14 to 24. The finer grains are used for the grinding of highly finished and polished parts, such as are turned out by the thousand in automobile factories. But we want to grind away steel rapidly and do not need a polished surface. Accuracy to within a few thousandths, yes, but finish, no.

One of the first variables we strike is the composition or material in the abrasive itself. Most of us are familiar with the terms carborundum, alundum, crystolon, etc., but these are trade names designating a particular manufacturer's product. Modern abrasives are made in the electric furnace and fall into two general classes—the aluminum oxides and the silicon carbides. But alundum, which is the registered trademark of the Norton Company and is formed by fusing a soft clay-like mineral called bauxite in the electric furnace, is produced in several forms. They are the regular, 38, 19, 98, 35 and 15. Other manufacturers have their own trade names and products. So we cannot specify by name, as we do not want to shut out competition.

The next item of many variables is the bond. The bond is the material in the grinding wheel that attaches each grain of abrasive to its neighbors. What we want in a bond is a substance of sufficient strength to make a wheel which will not let the wheel burst under the high peripheral speeds now in use and yet will permit the dulled grains to break out and bring new grains of abrasive with their sharp cutting edges to the surface. The amount of bond makes the difference between so-called hard and soft wheels. As a matter of fact, the abrasive itself in all wheels is extremely hard.

The silicate and vitrified bonds permit cutting speeds up to 6500 surface feet per minute, and the Bakelite, rubber or other organic bonds are operated at 9500 feet per minute. For the thin cut-off wheels, they are run at 16,000 feet per minute. The type of bond is an important feature in grinding wheel specifications, as it fixes the maximum speed at which the wheels can safely be operated.

Another variable after the type of bond has been selected is the grade or strength of the bond. Wheels are known as hard or soft, and in some scales the letters of the alphabet are used, grades E F and G being very soft; L, M, N and O medium; and T, U W and Z very hard. Still another variable within the bond itself is the "pores". These are the voids between the grains and the particles of bonding material and designate the "structure" of the wheel. What we want is a wheel that will cut freely and yet will not wear out too fast. Some wheels will do ten times the amount of grinding as others costing more and wearing out sooner. Our only suggestion is to explain to reputable manufacturers the kind of grinding to be done and the type of machine to be used, and trust his judgment and experience to recommend the best wheel. When other makes are offered, try them and decide which does the most work for the least total expense.

SAFETY CODE

Instructions for the Use and Care of Abrasive (Grinding) Wheels[1]

General

1. All abrasive wheels shall be provided with protection hood or wheel guard and protection flanges of steel.

2. Grinding machine on which the abrasive or grinding wheel is used must be sufficiently rigid and substantial to minimize vibration.

3. Grinding wheels should only be used on the machine for which they are shown on the accompanying list, unless otherwise instructed by the proper authority.

Storage

4. Extreme care must be taken in the storage of grinding wheels. Suitable racks or bins shall be provided to accommodate the various types of wheels carried in stock.

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[1] Based on the American Engineering Standards Safety Code for the Use, Care and Protection of Abrasive Wheels. published by the American Standards Association. 29 West 39th Street, New York, N. Y.

5. Straight and tapered wheels, ½-inch or more in thickness, are best supported on edge in racks. Thin rubber, shellac and other organic bonded wheels should be laid flat to prevent warpage.

6. Cylinder wheels and cup wheels should be stacked on the flat sides with cushioning material between them.

7. Grinding wheels absorb moisture and when left exposed to rain, dew or fog must be carefully protected, for if a portion of the wheel is exposed, it will absorb water and throw the wheel out of balance, causing excessive vibration while operating at high speeds and may result in the breaking of the wheel with perhaps a resultant personal injury.

8. Grinding wheels must never be placed on damp or wet ground even for short periods of time.

Inspection

9. All *grinding wheels* must be closely inspected before mounting to make sure that they have not been injured in transit or otherwise. As an added precaution, wheels should be tapped gently (while suspended) with a light implement, such as a screwdriver. Wheels should be dry and free from sawdust when applying the test, otherwise the sound will be deadened. Organic bonded wheels do not give the same clear metallic ring as do the vitrified or silicate wheels. If they sound cracked they should not be used.

10. All *grinding machines* must be inspected each day by the operator to see that the arbors, adaptors, or other machine parts on which the wheels fit are free from wear. When signs of wear are seen, new parts must be obtained and applied.

Speed of Grinding Wheel

11. The recommended speed in rpm and the tested speed in rpm will be shown on a label on each wheel by the manufacturer. Before applying a grinding wheel the grinding machine operator shall see that the recommended speed shown on the wheel is not less than the speed of the grinding machine.

12. The speed of all grinding machines must be checked daily by the machine operator, and when the speed is in excess of that shown on the authorized list for the particular make of machine, adjustment must be made to give the machine proper speed (see Appendix for surface feet per minute at various speeds).

13. Where the speed of the wheel spindle is adjustable, speed adjustment shall be made by an authorized person only.

Application

14. Grinding wheels must fit freely on the spindles and should not be forced on, nor should they be too loose.

15. Washers or flange facing of compressible material, such as blotting paper must be fitted between the wheel and its flanges.

16. When tightening spindle nuts, care must be taken to tighten them only enough to hold the grinding wheel firmly; otherwise the clamping strain is liable to damage the grinding wheel.

Starting New Grinding Wheels

17. All new grinding wheels shall be run at full operating speed for at least one minute before grinding, and the first contact made with the wheel, on the material to be ground, should be light to allow the wheel to become heated, so as to permit any defects in the wheel to indicate their presence, during which time the grinding machine operator must place himself to one side, out of range of any possible danger if the wheel should break.

Grinding Operation

18. The grinding machine operator must not place himself in a hazardous position, nor allow any of his fellow-workmen to do so, while the grinding machine is in operation.

19. Grinding on the flat sides of straight wheels, or the side of cup wheels, is prohibited.

20. Wheels out of balance through wear, which cannot be balanced by truing or dressing shall be removed from the machine.

Wheel Breakage

21. Whenever a grinding wheel breaks, a careful inspection shall be made to make sure that the hood or guard has not been damaged, nor the flanges bent or sprung out of true or balance. The spindles and nuts shall also be carefully inspected. A full report of each broken wheel must be made to the Chief Engineer M.W.

Appendix D

(7) SELECTION AND TRAINING OF MAINTAINERS AND OPERATORS OF WORK EQUIPMENT

C. H. R. Howe, Chairman, Sub-Committee; G. J. Ermentrout, Robert Faries, Paul Hamilton, E. H. Ness, C. H. Ordas, E. Pharand, J. G. Sheldrick, G. R. Westcott, Fred Zavatkay.

The necessity for increasing production in handling track maintenance work to meet the requirements of modern train operation, greater wheel loads and increased speed, has resulted in the use of heavier rail sections and a general improvement in the standards of track construction.

The use of heavier material and the necessity for obtaining a more uniform quality of track adjustment has created a demand for mechanical power to supplement manual labor. To supply this demand, power tools and equipment covering a wide range of utility have been produced, particularly during the past ten years. The extent to which the introduction of mechanical power has gone will be appreciated from the fact that the American railways now have $100,000,000 invested in such equipment. The responsibility for obtaining a fair return on this investment should receive the careful consideration of all officers under whose direction work is undertaken.

The possibilities in regard to the maximum usage of the different types of machine have been outlined by this Committee in the report published in Vol. 32 of the Proceedings, page 455, under the heading "Methods of scheduling and assigning of work equipment, giving particular attention to equipment used in seasonal work". While it is evident from the report that the greater the use obtained from a machine the greater will be the return on the investment, it is quite obvious that the annual upkeep costs will be larger. It is also self-evident that to obtain the full use of equipment, systematic methods of handling repairs must be established. This subject has received the attention of this Committee and it is covered by the report in Volume 32 of the Proceedings, page 375, under the heading "Best practices of maintaining labor-saving devices on construction and maintenance of way work, and the organization of the necessary supervisory force".

The ideal method of machine maintenance is that of scheduling general overhaulings at stated periods and keeping running repairs at a minimum. To obtain this result it is necessary that proper care be taken of the machine when in use and while idle.

It seems hardly necessary to point out that not only are repairs caused by neglect, or misuse, costly, but untimely breakdowns while work is going on may cause expensive delays due to disorganization of forces. As an illustration of the loss possible: A fully power equipped rail renewal gang may contain as many as two hundred men. The breakdown of a single machine may delay the entire force. If the delay lasts only ten minutes it will cost the railway company approximately fifteen dollars in lost wages, or the equivalent in cost of renewing three hundred and ninety feet of rail, $0.04 per foot. Numerous other instances might be cited of definite losses and also of those less tangible losses due to interference with traffic.

We may assume that railroads in general have provided supervision and have established means for taking care of general overhauling. The problem then becomes one of keeping down the cost of depreciation and running repairs through proper care and operation of the equipment. As this is a matter largely in the hands of the operators of the various machines, study of this feature is considered the essential subject of the Committee's assignment, "The selection and training of maintainers and operators of work equipment".

Selection of Men

In the selection of men for these positions, omitting from this discussion consideration of mental, moral and physical attributes, which are essential in all employees; the primary qualifications are natural mechanical aptitude, orderliness about machinery and ingenuity. The first of these qualifications is practically indispensable. Orderliness is a very good indication of the service that can be expected from the man and the equipment in his charge. Ingenuity may perhaps be better defined as the happy faculty of adaptation in an emergency.

Maintainers usually are selected from the ranks of operators, and in general will be found to owe their promotion to the outstanding possession of the three mentioned qualifications.

At the present time, due to scarcity of employment, much greater care can be exercised in the selection of men for any position than has been possible in the past. It is important that proper selections be made at the outset, for in many cases the existence of craft agreements, basing transfers and promotions on seniority, render it difficult to adjust matters of improper selection of men.

The general use of automobiles, trucks, tractors and similar equipment has resulted in a far more widespread knowledge of the fundamental principles of machine construction and operation than formerly. It is quite natural that possession of slight knowledge should create a desire for further information. This is particularly true in the case of the mechanical arts, and the result has been the establishment of manual training schools and courses throughout the country. Thousands of boys have had this type of instruction, and many of them are no doubt available and would be glad to fill positions as operators if the job is made permanent and the wages reasonably attractive. Without doubt railways would benefit through having intelligent operators on definitely assigned machines.

Training of Maintainers and Operators

We may assume that the maintainer has sufficient knowledge and experience to be able to operate and maintain all equipment and tools under his jurisdiction. His training is largely a matter of personal instruction on the part of the Supervisor of Work Equipment. He should be thoroughly schooled in the instructions for the care and use of equipment issued by the railway company and in addition he should be thoroughly familiar with the instructions and parts lists issued by the manufacturers of each machine that he has to maintain. He should be encouraged to visit, when conveniently located, the manufacturing plants of the makers of his machines, in order to improve his knowledge of the quality of materials used, assembling processes and other useful information.

The problem of training equipment operators on a railway is entirely different from that at an industrial plant. At the manufactory the instructor is in constant touch with the beginner and can continue his attention until the man is an adept at the operation and care of the machine. In fact, when machines of the same type are numerous, and being put into service at the same time, it is possible to conduct classes of instruction until the new men become capable operators. It is seldom the case that a railway installs many similar units simultaneously, and even when this is done the machines are likely to be distributed at widely separated points. As the cost of sending the prospective operators to a central point for training is prohibitive, the problem then becomes one of local instruction by the maintainer.

As the maintainer must continue his other duties, the time that he can give to instructional work is limited, so it will be seen that personal attention must be supplemented by other means. Quite often there is an experienced operator on the local territory who can be used as instructor at very little added expense. Also many manufacturers maintain a staff of service engineers who are readily available for this purpose. In general, the matters of primary instruction is not difficult; the real problem being that of securing uniformity of operating practice and care in maintaining the equipment.

To obtain the results mentioned it is first necessary to formulate standard practice rules and exercise proper supervision to insure that the instructions are followed. Practically all equipment manufacturers publish instructions governing the use and care of their machines. This information should be incorporated in the railway's own instructions concerning the use of equipment. It is customary, for practical purposes, for the railway to consolidate the individual machine instruction rules in a single publication, or rule book. The Committee has found that a good many railways have done this. However, there is considerable variation in practices, some being based on sound principles while others are founded on fallacious theories. Sub-Committee No. 11, of this committee has, for the past few years, been undertaking a study of this subject, and expects to present a "Manual of instructions for care and operation of maintenance of way equipment". This publication will consist of the recommendations from the manufacturers and such practices as have, through experience, proved meritorious. This manual when adapted to local conditions should be of general value to all railways.

Your Committee's study of this assignment leads to the following conclusion:

The extent of the railway's investment in roadway work equipment requires the establishment of systematic methods of protecting that investment, and securing the maximum return on the money involved.

To obtain this result it is our recommendation that:

1. Proper care be given to the selection of prospective operators.

2. That the appointment of an operator should be preceded by placing him with an experienced operator for a period of training. During the training period he should familiarize himself with that portion of the Manual of Instructions that pertains to the particular machine until his qualifications are proved by means of an examination by the maintainer.

3. That division and other officers directly responsible for the use of work equipment, thoroughly familiarize themselves with the contents of the Manual of Instructions in order that they may properly supervise compliance with the rules.

Appendix E

(8) CONCRETE MIXING AND CONCRETE HANDLING MACHINERY

N. M. Trapnell, Chairman, Sub-Committee; W. A. Batey, J. T. Derrig, J. F. Donovan, F. S. Hewes, F. W. Hillman, R. A. Morrison, C. H. Morse, T. M. Pittman, Fred Zavatkay.

The discovery of the advantages of steel as a reinforcement for concrete some seventy years ago has made the latter one of the most valuable materials available in engineering construction. Today, concrete is used for an almost endless variety of structures, such as bridges, culverts, buildings, retaining-walls, dams, abutments, tanks, bins, conduits, chimneys, piles, poles, etc. Its widespread use had led to the development of a considerable number of different methods of preparation and application.

Concrete mixing and handling machinery is made in many different sizes and types to meet the multitude of varying conditions encountered on the numberless jobs for which concrete is used. These jobs range in size from the construction of a small machine foundation, involving the pouring of only a few cubic feet of concrete, up to the construction of huge dams and bridges, which require the mixing and pouring of thousands of cubic yards.

The kind of equipment best suited to a particular job depends on such conditions as—

(A) The design and extent of the structure to be poured.

(B) The location of the job relative to transportation facilities, such as railways, navigable rivers, or highways, over which the raw materials, such as sand, gravel and cement, are to be transported to the job.

(C) The distance of the job from the sources of supply of the raw materials, which affects the ultimate cost of such materials.

(D) The time available in which to complete the job and the available labor supply.

(E) The local topography and water supply which in some cases affects the location of the mixing plant and the distribution of concrete on the job.

Most railroad jobs of any considerable extent, which require the mixing and pouring of large amounts of concrete, are handled by contractors and such details as the kind of concrete mixing and handling equipment used are of little interest to railroad officers. However, there is much work performed by the Maintenance of Way and Construction forces which requires the mixing and pouring of concrete, and a general knowledge of this equipment is of value to those responsible for such work. The value of such knowledge lies in the ability to determine the most economical kind of equipment to use under the conditions obtaining on the work involved.

It is, of course, impossible to lay down hard and fast rules governing the kind of concrete mixing and handling machinery to be used on a particular job because of the wide variation in local conditions. The purpose of the present report is to describe briefly the various types of equipment available and to outline the general classes of work to which these types are best adapted.

CONCRETE MIXERS

The purpose of the concrete mixer, as its name implies, is to thoroughly mix the various materials which go to make up the concrete, such as cement, sand, gravel and water, preparatory to being poured into the forms. It consists essentially of a horizontal hollow metal drum, having a central opening at one or both ends and arranged to rotate about its horizontal axis. The inner circumference of the drum is fitted with a series of mixing blades or buckets which churn the materials when the drum is rotated and thus facilitate mixing. The various materials are charged into the drum through the opening at one end and the completed mixture is discharged from the same opening or the opening at the opposite end where such is provided. The discharge is accomplished by tilting the drum or by means of a movable chute which, when placed in position in the drum, catches the mixture as it falls from the mixing blades when the drum is rotated.

The drum is usually conical in shape on tilting mixers and is cylindrical on the non-tilting type. It varies in size from 2½ cubic feet capacity up to 112 cubic feet capacity of mixed concrete. In all but the smallest sizes, it is supported on rollers bearing against track rings on its outer circumference to provide for rotation and is equipped with a ring gear for connection to some form of power drive. In the smallest sizes, having only one opening, it is carried on the end of a short shaft mounted in bearings, and is gear-driven, as are the larger sizes. The drum rotates at a speed of from 10 rpm for the larger sizes up to 20 rpm for the smaller sizes and the mounting provides not only for rotation, but, in the tilting type, for the tilting of the drum also.

The mixing drum is usually driven by means of a gasoline engine, or an electric motor, through spur gears or a sprocket chain and gears, the engine or motor usually being mounted on the same frame as the drum. Some mixers are designed to be driven by means of a belt connection from an external source of power, some are gear-connected to a steam engine and some of the smallest are driven by a hand crank. The majority of concrete mixers in service today are gasoline engine driven, the engines ranging in size from single-cylinder 1½ HP hopper-cooled units up to units of 50 HP having four cylinders and radiators for cooling. The electric motors used cover approximately the same range of power as the gasoline engines and may be obtained for direct current or for alternating current of any standard voltage and frequency. Most of the largest concrete mixers are driven by electric motors, although some of them are steam driven.

There are various means employed for charging the materials into the mixing drum. In the smallest sizes, the sand, cement, etc., is shoveled or dumped direct into the drum by hand. Usually, however, some form of charging device is provided. In many cases, particularly on the larger mixers, this consists of a fixed hopper in which the batches of material are placed and is so mounted that the contents can be fed into the drum by gravity through a hand operated gate. The most popular device consists of a skip-pan or power loader, the mouth of which is pivoted or hinged adjacent to the opening in the mixing drum, and to the opposite end of which are attached hoisting cables. This opposite or outer end can be raised by power from the driving unit acting through clutches, gears, shafts or chains, cable drums and the cables. The materials are placed in the skip when in its lowered position. It is then hoisted until its contents flow by gravity into the mixing drum. The lowering of the skip is controlled by a hand operated friction brake. Many mixers are equipped with a power driven vibrating or shaking mechanism which vibrates the lower end of the skip when in its raised position, to facilitate the flow of its contents into the mixing drum.

Water is introduced into the mixing drum of the smaller machines by means of a hand hose or bucket. Most of the larger machines are equipped with a measuring tank mounted above the mixing drum from which a definite amount of water can be fed by gravity through a pipe or spout projecting into the open end of the drum. The measuring of the water is accomplished by tilting the tank itself or by some form of measuring device contained in the tank, usually a tilting trough, and it can be set to control the amount of water delivered from the tank for each batch in order to maintain the proper ratio of water to cement. The tank is filled, usually, by a hose connection from a pressure line and is often equipped with a float valve which automatically controls the flow of water into the tank.

The discharge of the completed mixture, as mentioned previously, is accomplished either by tilting the drum or by a delivery chute or spoon which, when swung into position, projects into the drum and catches the mixture when it falls from the mixing blades as the drum is rotated. The mixture flows from the chute by gravity into whatever equipment is provided to distribute the concrete on the job. The discharge chute, which is carried on a system of levers, is swung clear of the blades during the mixing process. The drum tilting device is power-operated on the large mixers and is operated by a hand gear or lever on the smaller ones.

The mixing drum, power plant, charging and discharging equipment and all the necessary auxiliary machinery are mounted on a common frame making the concrete mixer a self-contained unit. The design of the mounting varies considerably depending on the kind of work for which the mixer is to be used. Although very few installations may be considered as permanent, there are many, particularly on large jobs, which may be considered as of a semi-permanent nature. These are usually provided with a skid-type mounting which allows the mixer to be moved from place to place on motor trucks or railway cars and set up on temporary foundations at the job. The few permanent concrete mixer installations are located in large cities where concrete is distributed ready mixed to various jobs by motor truck. In these, the mixer is mounted on permanent foundations with suitable conveyors and hoppers for handling the materials to be charged into the mixing drum and for handling the concrete to the trucks when the mixing is completed.

The majority of concrete mixers in service are portable and are mounted on wheels to provide for convenient movement from place to place. This is particularly true of the smaller units. The wheels may have plain steel tires to provide for movement by hand or by tractor over soft ground or they may be flanged for running on railway tracks. They may have solid rubber tires for running on hard pavement or they may be provided with pneumatic tires and the mounting arranged as a motor vehicle trailer for high speed movement on highways. Some mixers are mounted on a motor truck chassis to provide for the mixing of concrete in transit from the point where the materials are received to the point at which the concrete is to be poured. Many mixers have mountings designed for special purposes, such as street paving. These are often self-propelling and are equipped with means for weighing the concrete and delivering it direct to the forms.

There are several special devices and attachments which may be applied to concrete mixers. These include batch meters for recording the number of batches mixed and to insure uniform mixing, skip scales for weighing the materials for each batch, weighing hoppers for determining the weight of the mixed concrete delivered, winch or capstan drums and various kinds of power take-offs for driving other machinery from the power plant when the mixer is not running. There are also available oil-burning heaters designed to be mounted on the mixer, in which the flame is directed into the drum to prevent freezing in cold weather. The value of these special appliances depends on the kind of work to be done.

RELATIVE MERITS OF VARIOUS TYPES OF CONCRETE MIXING MACHINERY

In considering the relative merits of the various types of concrete mixers and their appliances, it should be borne in mind that each was developed for some general class of work and its design is a result of experience under the conditions obtaining on the kind of work for which it is intended. Thus there are small portable mixers for use on small jobs, which can be readily moved from place to place, there are mixers of large capacity for use on large projects such as the buildings of dams or bridges and which are set up as permanent installations for the duration of the construction work and there are self-propelling mixers equipped with special appliances for use in street paving, etc. Concrete mixers fall into two general classes, according to the method of discharging the mixed concrete from the drum, i.e., tilting and non-tilting.

Except in the smallest sizes, the mounting and driving mechanism of the tilting mixer is more complicated and expensive than that of the non-tilting type. However, its rate of discharge of the mixed concrete is faster and the drum clears itself more completely. It is well adapted to work where the concrete must be delivered intermittently in complete batches and is made in all sizes from the smallest to the largest. Practically all of the smallest mixers in service are of the tilting type because of the convenience in charging and discharging. Most of the largest units are of the tilting type because of the rapid discharge.

Although the non-tilting mixer is somewhat slower to discharge and does not clear itself quite as well as the tilting type, its mounting and driving mechanism is simpler and less expensive and it generally occupies less space. It is well suited for work where the space available for the mixing plant is limited and where the concrete is delivered more or less gradually in small amounts and where the mounting of the tilting type is not practical such as on a motor truck or trailer chassis. It is widely used on street paving machines, and is made in nearly as great a range of sizes as the tilting type.

The simplest form of charging equipment is the fixed hopper in which the materials are placed and from which they are fed into the mixing drum by gravity. Most of the smallest mixers are equipped with this device, as the hopper is low enough to allow the placing of the materials with a hand shovel from the ground. In the larger mixers the use of the fixed hopper is less convenient as it is too high to be reached from the ground, but must be reached by a raised platform and ramp or some other form of elevating device. However, most of the largest mixers are equipped with fixed charging hoppers as the weight and volume of the materials handled are so great as to preclude the use of a skip or power loader attached to the machine. It is also popular in large cities where union demands on power loader types make labor costs high.

On portable mixers of medium size the skip or power loader attached direct to the machine, is the most convenient charging device. The skip pan, when in its lowered position, is easily reached from the ground for placing the materials and is then hoisted by power until the materials flow by gravity into the mixing drum. It is the most popular charging device and is installed on practically all portable mixers which are not so small as to make its use unnecessary or so large that the quantity of material handled exceeds its capacity.

The electric motor is the simplest and cheapest power plant for concrete mixers. However, it has the disadvantage of being dependent on an external source of electric current and its use is restricted to locations where such power supply is available. Most permanent concrete mixer installations are electric driven as are the semi-permanent installations on large construction jobs. Some portable concrete mixers used by Power Companies in and about large cities are electric-driven, as are some mixers used indoors or below ground.

The most widely used power plant for concrete mixers is the gasoline engine. It is mounted complete with fuel tank, magneto and cooling system and makes the mixer an entirely self-contained unit independent of any external source of power supply. It is available for practically all sizes and types of mixers. Its principal disadvantages, compared to the electric motor, are its higher first cost and maintenance cost and the fact that it is somewhat more complicated to operate.

The skid form of mounting is, of course, the simplest and least expensive. However, it does not provide for ready movement of the mixer from one job to another. It is used principally for semi-permanent installations on large construction jobs where the mixer is of large size and not readily adaptable to mobile mounting.

Since most concrete mixer installations are temporary and the machines must be portable, the mobile type of mounting is the most popular. It consists of two or four wheels or, in some cases, of crawler treads for carrying the complete machine, and some form of coupler or attachment for pulling the machine from one job to another by means of a motor vehicle or by hand. The kind of wheel treads used depends, to some extent, on the character of surface on which the machine is to be moved. For general service steel wheels with broad flat tires are widely used. If the mixer is to be run on hard smooth surfaces, such as floors or runways the wheels may be equipped with solid rubber tires, in order to reduce wear and tear on the runways and the machine. There is also a combination of these in which the broad flat wheel rims are fitted with narrow rubber tires. This adapts the machine to movement over both soft or rough ground and over hard-surfaced runways. If the mixer is to be moved over highways as a trailer to a motor vehicle the wheels are usually equipped with pneumatic tires.

Some mixers for special purposes are made self-propelling and are mounted on crawler treads. These are used principally for street or road paving and are too cumbersome and expensive for general work. Another form of mobile mounting well adapted to a special purpose is that in which the mixing plant is mounted on a railway flat car and is usually equipped with conveyors for handling the materials from adjacent cars. It is sometimes used in railroad work when pouring pole or tower foundations, tunnel linings, etc.

THE SIZES OF CONCRETE MIXERS AVAILABLE

Concrete mixers are rated on the amount of concrete delivered per batch. Mixer sizes are based on batches of concrete, assuming a mixture of cement, sand and 1½-inch crushed stone with not to exceed 1¼ gallons of water per cubic foot of mixed concrete. A one bag batch of 1–3–6 ratio is equivalent to about 7 cu. ft. of mixed concrete, and this unit is generally used in rating the capacity of mixers. The rated capacity for unmixed dry materials is based on 35 per cent voids and is approximately 57 per cent greater than the mixed capacity. The output rating, usually expressed in cubic yards per day, is based on 40 batches per hour and a 10-hour working day.

The following table shows the standard sizes of concrete mixers available, giving mixed and unmixed capacity, output, power required and the number of bags per batch, based on a 1–3–6 mixture:

Capacity Mixed Concrete	*Capacity Unmixed Materials*	*Output Per 10-Hr. Day*	*Power Required*	*Bags Per Batch*
2.5 cu. ft.	4.0 cu. ft.	37 cu. yd.	1.5 HP	¼
3.5 " "	5.5 " "	50 " "	2.0 "	½
5.0 " "	7.5 " "	74 " "	3.0 "	½
7.0 " "	11.0 " "	100 " "	5.0 "	1
10.0 " "	16.0 " "	148 " "	7.5 "	2
14.0 " "	22.0 " "	200 " "	10.0 "	2
21.0 " "	32.0 " "	310 " "	15.0 "	3
28.0 " "	45.0 " "	415 " "	20.0 "	4
40.0 " "	64.0 " "	590 " "	30.0 "	6
56.0 " "	88.0 " "	800 " "	40.0 "	8
112.0 " "	178.0 " "	1600 " "	75.0 "	18

The most economical size of mixer to use on any particular job from the standpoint of operating cost will depend on the amount of concrete to be poured and the time available for completing the work. In other words, it is governed by the output of the machine. However, it is only rarely that any one job is large enough to justify the purchase of the most suitable mixer. In most cases and particularly in railroad work the size of mixer used depends on the equipment owned by the user.

The economics involved in this question depend on several factors. Thus a small cheap mixer may slow up the work of pouring concrete on a certain job and thereby increase construction costs. On the other hand a larger and more expensive mixer which will mix concrete as fast as it can be poured may hold down construction costs while in use, but may offset this by increased overhead expense if it stands idle a considerable part of the time. In general, a user who has sufficient work to keep his mixer in service practically continuously can justify ownership of a larger machine than one whose work is more or less intermittent.

As pointed out previously, most railroads cannot justify ownership of large mixers, say of over 2-bag or 10 cu. ft. mixed capacity. Any jobs requiring larger mixers are usually handled by contractors. A few large railways which perform a considerable amount of construction work with their own forces have the larger mixers, however, in most cases the railroad mixer must be idle a large part of the time.

The concrete mixers best suited for general use by railroad maintenance of way and construction forces are from ½ bag or 3.5 cu. ft. mixed capacity to 2-bag or 10 cu. ft. mixed capacity. They are of the portable tilting type, gasoline engine driven, and mounted on four steel wheels with plain flat rims. They are generally equipped with a skip or power loader, and a nigger-head or winch drum attachment has been found desirable.

CONCRETE HANDLING MACHINERY

The term concrete handling machinery is considered to include all devices and equipment used to convey the concrete from the mixing plant to the forms. There is a considerable variety of such equipment available and the type used on any particular job is affected by local conditions to an even greater extent than is the type of mixer used. Concrete handling machinery falls into two general classes, i.e., mobile and stationary. Usually a combination of the two is used.

The simplest and least expensive form mobile equipment is the ordinary wheelbarrow. It is loaded with concrete at the mixer, wheeled by hand to the job and the concrete dumped or shoveled from it into the forms. It has a capacity of 1½ to 2 cu. ft. of mixed concrete. Because of its small capacity and the labor required to move it, the wheelbarrow is most suitable for use on small jobs where the concrete must be moved only a short distance from the mixer and where the expense of more elaborate and efficient equipment is not justified.

The concrete cart is a considerable improvement on the wheelbarrow. It consists of an open-top steel body, approximately semi-circular in longitudinal cross-section, carried on two large wheels and equipment with handles at one end for pushing. The body is so mounted that its center of gravity is below the wheel centers. This provides for stability while in motion and allows for easy tilting when unloading. The cart is loaded from the mixer, pushed by hand to the job and tilted to allow the concrete to flow into the forms or other receptacle. It has a capacity of from 5 to 6½ cu. ft. and can be handled by one man. Because of its greater capacity and ease of movement it has a considerably wider range of use than the wheelbarrow.

The radial-gate concrete car is a further development of the two-wheel cart. It consists of a steel hopper mounted on four flanged wheels and is designed to run on tracks, usually of 24-inch gage. The hopper has a side outlet at the bottom which is closed by a lever-operated radial gate. The car is loaded at the mixer, is moved to the point of discharge, usually by means of a small locomotive, and is unloaded by opening the gate to allow the concrete to flow out by gravity. It has a capacity of from 24 to 32 cu. ft. of mixed concrete and is used on jobs requiring the movement of large quantities of concrete a considerable distance from the mixing plant where the use of wheelbarrows or carts would not be practicable.

Another form of mobile equipment is the concrete truck which consists of an open tank body mounted on a motor truck chassis. The tank is equipped with an agitator driven from the truck motor to prevent the concrete from setting in transit and discharge is accomplished by means of a hand-operated gate and chute in the bottom of the tank at the rear end. The front end of the tank can be raised by power to facilitate discharge of the contents through the gate and chute. These trucks have a capacity of from 1 to 8 cu. yd. of mixed concrete and are used principally to deliver ready-mixed concrete from central mixing plants.

The most widely used form of stationary equipment is the gravity placing plant. It consists of a tower or mast provided with a skip hoist, elevated hopper and radial chute for distributing the concrete to the forms. The concrete is placed in the skip or hoist bucket and is elevated and dumped into the hopper from which it flows by gravity through the chutes into the forms. The mast or tower is usually of steel construction and is supported by guy ropes or cables. The chute is made up in sections bolted together or provided with swivel joints where necessary and is supported by cables direct from the top of the mast or from a swinging boom mounted on the mast. It can be lengthened, shortened or swung radially as desired to reach all parts of the work.

The chute sections are made in the form of open troughs with arch bands or as closed pipes. They are 12 in. to 20 in. in diameter to meet various capacity conditions and are made in lengths of from 10 ft. to 50 ft. The 40 ft. and 50 ft. lengths are fitted with light trussing to provide proper stiffness and support. The angle of the chute with the horizontal should allow the concrete the flow without separation of the ingredients. In general, an angle of about 27° or one vertical to two horizontal, is considered good practice.

The mixed concrete is placed in the skip hoist direct from the mixer where the latter can be located close to the base of the tower, or by means of some form of mobile equipment, such as carts or hopper cars, where the mixing plant must be located some distance from the tower. With the former the hoist is often operated from a winch drum on the mixer. The design of the plant should be such as to insure a continuous stream of concrete in the chute. Its size will, of course, be governed by the quantity of concrete to be poured and the extent of the work.

Another type of gravity placing plant consists of an inclined track carried on trestlework, provided with a hopper and gravity chute at its upper end and on which runs a skip car operated by cables from a winch drum on the mixer located at its lower end. The mixer discharges the concrete direct into the skip car which is then pulled up the incline and the concrete dumped into the hopper from which it flows through the chute to the forms. The chute can be adjusted as to length and direction in the same manner as in the mast or tower placing plant.

The inclined track gravity plant is generally used on smaller jobs than the mast or tower plant. It is a somewhat more self-contained unit and the trestle can be readily taken down and re-erected in a new location. The plant can be made portable by mounting the trestle and mixer on a string of railroad flat cars. This has been done on several occasions when building viaducts and similar structures. The cars are moved along a track parallel and close to the structure from one location to another when all forms within range of the chute have been poured in each location. In general, the inclined track plant is easier to set up and take down than the mast or tower plant, but it does not cover as wide a range of work.

The dump bucket may also be classed as stationary concrete handling equipment. It consists of a circular steel bucket, or hopper, mounted on legs and is provided with a yoke or lift-bar at the top for hoisting and a knife-type sliding gate at the bottom to control the discharge of concrete. It is made in sizes of from 36 cu. ft. to 118 cu. ft. capacity and is used principally in conjunction with gravity placing plants where the flow of concrete to the forms must be carefully controlled. It is set up or suspended over the forms to be poured and is fed with concrete from the gravity chute. The flow of concrete to the forms is controlled by the gate.

Conclusion

The past and future design of concrete mixing and handling machinery has been and will be influenced by the requirements of contractors to a far greater extent than by the requirements of railroads. This is because most of the mixing and handling machinery in use, even on railroad jobs, is owned and operated by contractors.

There are avaliable today sufficient kinds or types of such machinery to suit all railway requirements.

In view of the great influence of local conditions on the kind of equipment used, it is considered inadvisable to make definite recommendations regarding concrete mixing and handling machinery for railroad service.

Appendix F

(11) MANUAL OF INSTRUCTIONS

William Elmer, Chairman, Sub-Committee; W. A. Batey, G. E. Boyd, C. R. Edwards, R. C. Haynes, Harry Homans, C. H. Morse, H. E. Stansbury, N. M. Trapnell.

GENERAL

1. This manual is issued for the benefit of operators, foremen, master carpenters, supervisors, division engineers and others interested in the operation, performance and maintenance of machinery used in maintenance of way service.

2. It has been prepared, not with the idea of instructing the operator how to assemble or dissemble the major units of any equipment, but rather to help him to take the best care of it and so operate it as to obtain the maximum of service with the minimum of maintenance expense. All operators and others working on or about machines must be governed by the Book of Rules, the Safety Rules and all published instructions pertaining to the safe operation of machines. To enter or remain in service is assurance of willingness to obey the rules.

3. The arrangement of this manual is: (1) general instructions pertaining to all maintenance of way equipment, and (2) specific instructions covering individual types of machines. Each operator of a machine must become familiar with *both the general instructions and those pertaining to the particular machine of which he is in charge.*

GENERAL INSTRUCTIONS

Safety

4. SAFETY is the first and most important consideration. In all cases of doubt or uncertainty, the safe course must be taken and risks avoided.

5. A machine must not be allowed to foul or obstruct any track without first obtaining proper permission and providing proper protection as prescribed by Rules 99, 100 and 101–A, Book of Rules, Transportation Department. Violation of any of these rules or carelessness as to the safety of one's self or others, is sufficient cause for discipline.

Care of Machine

6. The first duty of every man in charge of or operating a machine is to keep it clean. An operator who fails to observe this rule usually neglects general maintenance of the machine. It is essential that the machine be clean to permit proper inspection, lubrication and adjustment. A dirty machine increases the hazard of personal injury to persons working on or about it. Care should be exercised in using waste or linty rags for cleaning gas engines or air compressors to prevent lint or other material being introduced into the fuel or oil lines, ultimately causing failure of the equipment. Gasoline should not be used for cleaning machinery, because of the fire hazard it introduces. Kerosene should be used for this purpose.

7. It is important that all regular and special tools, grease guns or lubricators, gages, extra parts or accessories, etc., be kept with each machine. All such items should be checked out when transferring a machine from one job to another.

8. Before starting a machine, the operator must familiarize himself with all parts, detail adjustments and lubrication of the machine to which he is assigned. During operation, frequent examination should be made to insure that all nuts and bolts are tight; that there are no cracked, broken or seriously worn parts; and that the grease cups and places that need lubricating have had proper care. A manufacturer's "Instruction Book" and "Repair Parts List" should be furnished each operator, who must study these until thoroughly familiar with them. If the instruction book is not available, someone familiar with the machine should instruct the operator how to handle and maintain it safely, and the instruction book and parts listed should be secured promptly, so that necessary repair parts may be properly described, and accounted for. Instruction books and parts lists should accompany machines when transferred from one operator to another, and those applying to each particular machine must be kept with the machine at all times for the guidance and instruction of all who participate in its operation. These books must be kept in suitable holders provided for this purpose, in the cab or tool box.

9. Trouble with machinery is due chiefly to the lack of knowledge and experience on the part of the operator. For this reason, repairs and adjustments must not be attempted except by one familiar with what is to be done and how to do it. If extensive repairs are required, the operator must consult with the maintenance of way equipment repairman or supervisor, to determine whether repairs should be made in the field or the machine sent to the shop.

10. When ordering parts the following information should be given:

(a) Name and make of device.
(b) Number and description of part, as given in the parts list.
(c) Railroad's serial number of machine.
(d) Manufacturer's serial number of machine.
(e) If the parts required are for engine, or accessories such as generators, magnetoes, etc. give make and manufacturer's serial number of the engine or accessory in addition to the part number and description.

11. The operator of every machine must familiarize himself with the entire lubricating system, provide himself with all necessary lubricants and with proper equipment for handling and applying them. *Lubricants should be those specified on lubricating charts.* Operator must be familiar with the various lubricants required, to safeguard against improper substitution which will result in damage to machinery. These features should be given careful attention, since neglect to keep a machine well lubricated indicates carelessness on the part of the operator and impairs the efficiency of the machine.

12. When through using a machine the operator must clean and lubricate it and know that it is in good condition before transferring it to another gang.

13. When shipping machines to or from the shop, from one division to another, or from one gang to another, a shipping tag should be fastened securely to the machine, if possible where it is protected from the weather. The tags should be 4 in. × 6 in., printed in black ink on yellow tag stock, as follows:

North & South Railroad

Place .... Date....................................
Shipped from .... At......................................
Shipped to .... At......................................
Prepared for Shipment by ....
Water Drained from Engine ....
Water Drained from Air Compressor ....
Gasoline Drained from Tank ....

List of Parts Missing

14. Receipt of a machine in dirty, unoiled, or poor condition in other respects, must be reported promptly to proper officer. Failure to do so implies that machine has been received in good condition and the one who has it then becomes responsible for defects that may be found later.

Gasoline Engines

15. As most machines are driven by gasoline engines operators should follow a procedure in handling them that will avoid injury to all persons near the machine, and damage to it. He should familiarize himself with his particular motor and with the characteristic "hum" when it is operating smoothly, so that he will recognize strange noises and investigate their origin. Unnecessary tinkering with equipment will not be permitted.

16. He should study the engine and its diagram as given in the instruction book accompanying the machine and leave it alone as long as it is working satisfactorily. Frequent examinations should be made, however, to ascertain that all nuts and bolts are tight and that the grease cups and places that need lubricating have had proper care.

17. The operator should not tamper with carburetor, magneto, primer, lubricating system or distributor unless he is absolutely sure that they require attention and that he is competent to make the adjustments required. Too much tampering and tinkering has ruined many engines. Adjustments must not be made to wires or engine while engine is operating.

18. When filling the gasoline tank, approved cans should be used. The nozzle of the gasoline hose or pipe must touch the tank to prevent sparks from static electricity. Smoking is prohibited, lights and fires must be kept away and the engine stopped before filling the gasoline tank.

19. The three essentials for proper operation in order of importance are:

1. Oil.
2. Water (if not an air-cooled engine).
3. Gasoline.

20. Running out of gasoline results in a short delay. Running out of water or oil results in long expensive delays for re-grinding cylinders, fitting new pistons and rings, and other costly work in the shop.

21. Lubricants, especially those used in servicing equipment along the right-of-way, should be kept in closed containers so that they will not become contaminated with grit or cinders from passing trains. Be sure that measures and funnels are wiped clean before and after using them.

22. It is essential to insure that all lubrication has been provided, and that the cooling system is ready to function properly before starting the engine. Where *two-cycle engines* are used, lubricating oil is to be mixed with the gasoline in the ratio of ½ pint of oil to one gallon of gasoline; except that in new engines or engines with re-ground cylinders the quantity of oil should be increased 50 per cent during the first 30 days of operation. In *new four-cycle engines* or where cylinders have been rebored or new rings applied, ½ pint of light oil should be mixed with each gallon of gasoline during the first 100 hrs. of operation, after which no oil need be added to the gasoline. Care should be exercised to avoid excessive use of overhead lubrication through the gasoline

system because of the effect it will have on carburetion. In adding the oil to the gasoline, the oil should be measured carefully. Depending on the color of the mixture to obtain the proper amount of lubricant is poor practice and must not be done. The oil must be mixed thoroughly with the gasoline by stirring with a wooden stick before placing it in the gasoline tank. It must not be mixed in the gasoline tank.

23. The timing of the spark is controlled automatically in some engines, but there are others in service on which spark timing is controlled manually. When starting an engine of the latter type, the spark must be retarded to avoid injury to the man cranking the engine. After the engine has been started, the spark must be advanced as far as possible, without causing loss of power or spark knock. Many engines have been damaged by operating them with the spark retarded. This causes overheating with danger of burning or warping the exhaust valves. In starting engines, care must be taken in warming them up to see that the oil is flowing freely before applying the load. When applying the load, the throttle must be opened slowly. Avoid racing the engine. When idling, cut the speed down as low as possible. Unnecessary idling is prohibited. When starting, do not speed the engine—racing induces high bearing pressures and excessive vibration. In cold weather serious damage may be caused by putting the engine to work before the lubricating oil has warmed up and had a chance to distribute properly. Before engaging the main clutch, all machinery should be out of gear, so far as possible, and the load applied gradually. When starting an engine by hand, in addition to precautionary measures relative to retardation of spark, the starting-crank handle should be grasped with the thumb on the side of handle with fingers, and the body kept as far away as possible so that in the event of accidental backfire there will be no danger of breaking the wrist or inflicting other injuries.

The proper procedure in starting a free-running gasoline engine is as follows:

(a) With ignition off, operate choke and turn motor over several times;
(b) Retard spark and turn on ignition;
(c) Give crank quarter-turn by pulling.

24. When engines are equipped with starting motors and storage batteries, the operator must inspect the battery every week to make sure that all cells are filled with liquid to the proper level and that the specific gravity of the liquid is correct. If filling is required, nothing but distilled water should be used. In cold weather the battery must be kept well charged since the battery will freeze if not well charged; and more power is required to start the engine in cold weather. Battery-charging ammeter must be kept in proper working condition at all times and battery not overcharged.

25. In the lubrication of a four-cycle gasoline engine it is of first importance to keep a supply of good oil in the crankcase. With a new engine, the crankcase should be drained after every 20 hrs. of operation for the first 100 hrs., and then after every 50 hrs. of operation. The best time to drain the crankcase is just after a run when the engine and oil are hot and the sediment is in suspension in the oil. It is essential that the proper amount of oil be maintained in the crankcase; insufficient oil will cause serious damage to the engine by burned-out bearings, scored cylinders or frozen pistons. Surplus oil is detrimental, causing excessive carbon deposits on cylinders, spark plugs, valves, etc. Carbon causes damage by cutting valves, valve seats and cylinders. Some of the carbon finds its way into the crankcase, mixes with the lubricating oil and causes excessive wear on the bearings. Oil-pressure gages must be kept in working order at all times and engines shall not be operated with an oil pressure below the minimum set for the particular engine. Low oil pressure is indicative of either insufficient oil, an improper working oil pump, damaged bearings, or excessively diluted or thinned oil. Oil filters should be cleaned every 500 hrs. or a new filtering element installed where the filter is of the non-cleanable type. Air cleaners should be inspected at every oil change and must be kept in good operating condition at all times.

26. The crankcase must not be flushed with kerosene. Kerosene adhering to the interior of the engine will tend to dilute the crankcase oil. Engines with crankcases which do not drain thoroughly should be flushed with a small amount of new oil. The drain should then be closed, and the proper amount of new engine oil added. Air-compressor oil, or light gas-engine oils, are excellent for flushing the crankcase.

27. Care must be exercised to avoid excessive use of the choke, or too rich mixtures of gasoline, as the surplus gasoline washes the lubrication off the walls of the cylinders and dilutes the crankcase oil, fouls the spark plug, accelerates the formation of carbon and may result in scored cylinders.

If the ignition switch does not function in stopping the engine the choke must not be used for that purpose. The engine may be stopped by removing wire from the switch and grounding it on frame or cylinder block. Improper functioning of ignition switches should be corrected at once.

28. The cooling system is extremely important. Frequent inspection should be made to insure that the radiator is full and not leaking. Under no condition should proprietary radiator no-leak solutions or other compounds be introduced into the cooling system for the purpose of plugging leaks. Pump glands should be kept sufficiently tightened to prevent water leakage, but not tight enough to cause scoring of the pump shaft.

The cooling system should be cleaned at least four times a year or oftener, if conditions warrant, as follows:

Fill the cooling system with a mixture of soda ash and water in the proportion of 1 lb. soda ash to 5 gals. of water; run the engine with the radiator covered or the shutters closed until the solution is brought to the boiling point; then shut down the engine and drain; after the engine has cooled thoroughly (this requires a period of from one to two hours), flush with clean water before refilling. The foregoing procedure should always be followed before adding anti-freeze solution and again in the spring when changing from anti-freeze solution to water.

29. Inspect fan belts of fan-cooled radiators periodically for proper adjustment. Flat belts should be kept tight enough to prevent slippage and maintain full fan speed, and the belt should be kept free from grease, using a belt dressing to preserve the driving surface. Fan belts of the V type do not require as much tension as flat belts, and usually run with a slight curvature in the slack side when properly adjusted. Extreme tension is detrimental to this type of belt, causing useless strain and rapid overheating which breaks down the internal structure of the belt.

30. Damage to engines from freezing usually occurs with the first frost and is largely the result of unpreparedness. For this reason, greater care should be exercised in the fall. When in doubt as to probable weather conditions, and anti-freeze solution is not available, the radiator and cooling system must be drained. (This applies also to the cooling system on air compressors). In draining cooling systems, all drain valves should be opened. The approved anti-freeze solution, if used should be mixed in the proper proportion with water, and applied to the cooling systems at a sufficiently early date to insure safety.

Completely denatured alcohol, 188 proof, or other approved anti-freeze materials shall be used in the radiators and cooling systems of all automotive type engines. Alcohol if used is to be mixed with water. Mixtures of alcohol and water will have the following characteristics:

Part by Volume		*Freezing*	*Specific Gravity*
Alcohol	*Water*	*Point*	*at 60° Fahr.*
20	80	20° F.	.976
30	70	10° F.	.9654
40	60	— 2° F.	.9518
50	50	—18° F.	.9343

If other approved anti-freeze materials are used, follow manufacturers instructions.

Careful inspection should be made to see that leaks are eliminated so that there will be no unnecessary waste of material. Any losses due to unforeseen leaks are to be made up with the proper mixture, and losses due to evaporation are to be made up with undiluted alcohol.

Kerosene must not be used as an anti-freeze solution (1) because of the fire hazard; and, (2) because dissolving pump grease will be carried over into the cooling system where it will become contaminated with rust, sediment or scale and settle over the upper openings in radiator, thus preventing circulation through the radiator.

31. During cold weather, with radiator cooled engines—a higher temperature of the cooling mixture (water and alcohol) will avoid condensation in the crankcase and maintain the normal efficiency of the engine. The higher temperature may be obtained by covering the lower portion of radiator with a thin piece of wood or cardboard.

32. If the engine develops a knock, it is important that the case be investigated and corrected at once. If not corrected, the knock will become more pronounced, causing loss of power and serious damage to the motor. If the engine is difficult to start, something is wrong and the trouble should be found and remedied.

33. The following chart shows adjustments or repairs to be made on gasoline engines not operating properly.

Adjustments or repairs to items marked (1) are to be made by the Department repairman.

Adjustments or repairs to items marked (2) are to be made by the operator.

Adjustments or repairs to items marked (3) are to be made by the operator, if possible; otherwise, by the Department repairman.

MOTOR HARD TO START	Weak battery. (2) Defective magneto. (1) (A) Worn brushes. (2) (B) Oil or water soaked. (1) (C) Breaker points adjusted. (2) (D) Breaker points renewed. (3) (E) Coils broken or soaked. (1) (F) Breaker arm or brushes sticking. (2) (G) Magneto weak. (1) Throttle or governor valves loose on shafts. (3)	Spark plugs fouled. (2) Spark plugs cracked. (2) Loose or defective wiring. (2) Wires connected to wrong plug. (2) Improper timing. (1) Improper gas mixture. (3) Gasoline flow obstructed. (2) Valve seats bad. (1) Valve tappets improperly adjusted. Intake manifold leaking. (2) Water in fuel supply. (2)
MOTOR MISSING	Spark plugs fouled. (2) Spark plugs cracked. (2) Valves warped or broken. (1) Valves or tappets stuck. (3)	Valve tappets improperly adjusted. Priming cups leaking. (2) Cylinder head gasket leaking. (2) Manifold gaskets leaking. (3)
MOTOR OVERHEATING	Lack of oil. (2) Oil badly diluted. (2) Lack of water. (2) Radiator clogged. (2) Water hose obstructed. (2) Water pump vane stuck. (3)	Carburetor choke valve partially closed. (2) Valves leaking. (1) Fan belt slipping. (2) Improper gas mixture. (3) Improper timing. (1) Spark retarded too far. (2)
MOTOR LACKS POWER	Valves holding open. (1) Valve seats worn. (1) Piston rings weak. (1) Piston rings stuck. (1) Improper gas mixture. (3)	Improper timing. (1) Muffler stopped up. (2) Governor or throttle valve loose. (3) Oil badly diluted. (2) Bad breaker points. (3)
MOTOR KNOCKS	Carbon in cylinders. (1) Loose main bearings. (1) Loose rod bearings. (1) Loose piston pin. (1) Worn pistons and cylinders. (1)	Magneto timed too early. (1) Loose push rods. (1) Motor overheated. (3) Loose flywheel. (1) Lack of oil or water. (2)
FAULTY CARBURETION	Carburetor improperly adjusted. (3) Valves leaking. (1) Intake manifold leaking. (3) Gaskets leaking. (3)	Shut-off valve closed. (2) Using too much fuel. (2) Water in fuel. (2) Sediment in fuel tank. (2)
EXCESSIVE SMOKE FROM EXHAUST	Too much oil in crankcase. (2) Carburetor needle valve open too far. (3)	Carburetor float sticking or leaking. (3) Lubricating oil thin—not sealing pistons. (2)
EXPLOSION IN MUFFLER	Ignition too late. (1) Weak spark. (3)	Exhaust valve holding open. (1) Exhaust valve warped. (1)

EXPLOSION IN CARBURETOR OR INTAKE MANIFOLD	Gas mixture too lean. (3) Intake valves sticking. (1) Intake tappets sticking. (1) Intake valve spring weak. (1)	Intake manifold leaking. (3) Intake valves warped or broken. (1) Intake tappets set too close. (1)
POOR COMPRESSION	Valves not seating. (1) Valves sticking. (1) Valve tappets sticking. (1) Valve tappets set too close. (1) Piston rings weak. (1) Piston rings broken. (1) Piston rings stuck. (1)	Loose spark plugs. (2) Cracked spark plugs. (2) Cylinder head loose. (3) Cylinder head gasket leaking. (3) Oil thin—not sealing pistons. (3) Scored cylinders. (1) Worn pistons and cylinders. (1)

34. Gas tanks must be inspected frequently to insure against leaks. If a leak occurs, it may be repaired in the field by soldering, using a hot soldering iron, but being sure that the tank is entirely empty, the fumes diffused, and the closing cap removed. A flame must never be applied to a gas tank.

35. Fumes may be diffused by *completely* filling tank with water, then draining.

36. When necessary to ship machines, the gasoline tank and the cooling system of engines must be drained thoroughly (see Par. 13.).

37. Magnetos must be oiled carefully but not more than specified in the manufacturer's instruction books, which is usually not more than one or two drops a week.

38. Engines must not be operated in small closed buildings, such as toolhouses, where carbon monoxide may be accumulated, as this gas is fatal.

SPECIFIC INSTRUCTIONS COVERING INDIVIDUAL TYPES OF MACHINES

Automobiles, Trucks and Tractors

39. Drivers or operators must be qualified and, where required, licensed under the laws of the states in which they operate.

40. All traffic rules and regulations must be observed strictly. Stops must be made at all railroad crossings and the driver must know what it is safe to cross before proceeding. When two men are on the truck, one must flag over the crossing on the ground.

41. The safety rules of the railroad must be observed.

42. No unauthorized person shall be permitted to ride on trucks or automobiles. Violation of this rule is sufficient cause for discipline.

43. Trucks must not be used for the transportation of other than company material or men, except as authorized.

44. Drivers must obtain and observe the instructions issued by the manufacturer of the particular type of automobile or truck to which they are assigned, paying particular attention to the lubrication chart and instructions. Operators must follow strictly the lubricating instructions contained in the lubricating charts.

45. No truck shall be operated on a public highway without displaying the prescribed license plates in the proper manner.

46. The license plates must be kept clean.

47. The chassis must be kept clean, especially around joints and bearing surfaces. When necessary, and in any event at least once a month, the chassis and running gear must be gone over with a kerosene rag to remove accumulations of oil and dirt. The bolts holding the body, power plant, fenders, etc., must be kept tight. Troublesome squeaks develop in the chassis, which can be remedied by using engine oil around the fastenings.

48. Care should be used in washing automobiles and trucks, as the high finish may be ruined by improper or careless washing. If soap is necessary plenty of water should be used to rinse the body thoroughly.

49. Mud, grease and oil must never be allowed to remain on the truck longer than is absolutely necessary. Mud must be soaked off with plenty of water but without rubbing. A common rubber hose without nozzle, such as is used in garages, is the best means for cleaning, but when used against the body the stream should be without force.

50. After washing, dry the body immediately with a clean chamois skin, otherwise the finish may become cloudy and streaked. All grit and mud should be removed before using the chamois skin.

51. It is most important that tires be kept properly inflated. The pressure must be tested at least once a week with a reliable pressure gage and not permitted to fall more than 10 per cent below the pressure recommended by the manufacturer.

52. If tire trouble develops on the road, the truck must not be run on a flat tire farther than necessary to stop and clear the road for traffic. Even 100 ft. will break the body of the tire between the rim and road, injuring both the casing and the inner tube.

53. Care must be taken in driving over rough roads that are hard on tires, and speed reduced accordingly.

54. Tire chains must be put on loosely so that they may shift gradually around the tire, equalizing the chain wear on the tires. When using chains they must be applied to both rear wheels. When used on one wheel the other wheel skids, causing undue wear.

55. Automobiles and trucks must not be driven in car tracks, as the rails will damage the tires.

56. Safe operation requires that the brakes must be used carefully and kept properly adjusted, so that the braking strain will be evenly distributed between the tires.

57. The tires must be protected as much as possible from oil or grease, which should be removed with a cloth soaked in gasoline.

58. The truck must not be loaded beyond its rated capacity.

59. Spare tires must be covered to prevent damage by solar heat, and rotated in service every three months.

60. Tractor operators must inspect all nuts and cap screws weekly and know that they are tight. They should never attempt to make adjustments while the engine is running. All wiring contacts should be kept tight and clean.

61. Care must be used in driving over rough ground, on ascending or descending grades and when the operation is in deep mud or water. When stopping tractor on grades, the brakes must be set.

62. Tracks on crawler type machines must be adjusted properly at all times and lower and upper track wheels must show evidence of lubrication, and revolving. Steering levers must be used carefully and steering bands must be kept adjusted properly.

Concrete Mixers

63. In setting up mixer for operation, it is essential that the machine be level and blocked properly.

64. The mixing drum must be kept clean and portions of former mixes not allowed to accumulate. This can be done by washing out the drum with water at the end of each run. Concrete must not be allowed to accumulate on the frame, wheels or other parts of the machines. Concrete accumulation should be washed off or knocked off at the end of each day's service. Road materials, or other bituminous or oily mixes must be made only in mixers that have been assigned to that service.

65. The loading skip must not be beaten by sledges, picks or other tools.

66. The lifting cables of skip must be kept lubricated and not permitted to kink.

67. The rotating mechanism must be kept in proper adjustment, clean and well lubricated.

68. The water must be drained in freezing weather and when shipped or not in use (see Par. 13.).

Cranes, Ditchers, Rail Loaders

69. Cranes, ditchers, rail loaders and similar equipment must discontinue work when trains are approaching or passing on adjacent tracks.

70. Swinging portions of cranes must be locked or mechanically fastened with the boom parallel to the center line of track during the approach and passing of trains on adjacent tracks.

71. If the work to be done involves the fouling of adjacent tracks, either by cab, boom or any other part of the equipment or by the load being handled, adjacent tracks must be protected as provided by Rule 101-A of the rules of the transportation department.

72. Where limit stops are provided on such equipment, which limit the swing, so that adjacent tracks are not fouled, and the work to be performed can be done within such limits, the stops are to be kept set at all times.

73. Where no limit stops are provided or the work requires the swinging of the crane beyond the limit stops, the adjacent tracks must be protected as provided by Rule 101–A (see Paragraph 121).

74. The operator must see that no one rides on the crane or on the cars occupied by the crane, except as duty requires, and he is then required to see that all precautions are taken to prevent injury.

75. The crane operator is required to ride in the crane when it is being moved in worktrain service, and to see that the center line of the crane is over the center line of the car, with boom properly anchored.

76. He must familiarize himself with the anchorage with which the crane is equipped for movement in trains. He must see that a notice is posted under glass in a frame placed in the cab, giving list of the anchors to be kept on the crane at all times, and the method of application and stating that operators are responsible therefor.

77. If the cab of the crane is equipped with doors, they must be locked when the machine is not in use.

78. When a crane, derrick, or other revolving machine is to be shipped in a non-revenue train, all anchors, lock pins and jacks must be secured in their proper order; when shipped in a revenue train, it must be loaded and rotating parts secured to meet the requirements of the Association of American Railroads loading rules. If the boom is dropped on a carrier or on the floor of the car, the rear end of the crane must be supported by suitable blocking to avoid damage to the center pin and rollers.

79. Two-part lines should be used for handling heavy loads. The cables and sheaves over which they pass must be kept well lubricated to prolong the life of the cable. Special care must be taken to avoid kinks in the cables.

80. When adjusting clutches and brakes, care should be exercised to avoid making them too tight, as this makes extra work for the operator in handling the machine, frequently wears out the lining and wastes power.

81. Booms may drop as a result of the boom hoist and clutches and the boom hoist brakes slipping. This is usually caused by a collection of moisture on the friction faces. To avoid this the clutches and brakes should be dried by rotating the machinery with the motor, slipping the clutches and brakes for several revolutions before attempting to handle a load.

82. Never apply rosin, belt dressing or similar compounds to brake or clutch bands, as this will create an extremely hazardous condition. One drop of lubricating oil applied to the band lining occasionally is all that is required.

83. When brake and clutch linings become saturated with oil, it is necessary to remove and clean them by soaking them in gasoline.

84. Under no circumstances should more than one line be separated from a single drum.

85. Before handling a heavy load, particularly where damage or personal injury may result from brakes or clutches slipping, they must be tested against each other to make sure that they will carry the load.

86. The operator must keep all safety guards in place when the crane is working.

87. Cranes should be equipped with warning whistles which must be kept in working condition.

88. Crawler cranes, ditchers, or cranes of similar construction, mounted on cars as operating units, must not be transferred from cars to which they have been assigned without permission from the proper authority.

89. Tools and machinery badge plates must be applied to all cranes to identify the boiler, crane, or other items of equipment. Manufacturer's identification number and/or class must be preserved on all cranes to facilitate the proper ordering of repair parts.

90. Each crane shall have posted in its cab, readily visible to the operator, the capacity rating of the machine for the various radii and load block loading conditions. Under no condition shall a crane be loaded beyond rated capacity on account of danger of upsetting or the failure of parts.

91. Under no condition shall a crane be operated with cable of size and construction other than that furnished by the original manufacturer or as prescribed by the proper authority.

92. All steam operated cranes require a State, City (or both State and City) certificate of approval of boiler used, or temporary permit to operate the boiler in territory

in which they are allocated. Arrangements must, therefore, be made, for the purpose of obtaining such certificates of boiler approval, or permits, to operate boiler in the territory in which cranes are allocated.

93. Inspection certificate covering the territory in which steam cranes are eligible for operation must be posted in the cab of each steam crane.

94. All cranes must be provided with safety appliances in accordance with ICC requirements and standard drawings. Safety appliances on cranes must be maintained in first-class condition at all times.

95. Locking pins, hold-downs, or devices to insure safe handling of crane in transit must be maintained in first-class working condition at all times.

96. Rotation limiting devices or stops must be maintained in first-class condition at all times.

97. Wreck cranes which are assigned to electrified territories, or which may be called upon to operate in electrified territories, must be provided with suitable cowling at boom and at cab to prevent personal hazards on account of overhead wires when operating.

98. Each operator of crane shall be furnished with an identification card certifying his qualifications to serve as operator. He shall be able to produce his operator's card when called upon at any time. Crane operator's card shall be renewed annually.

99. It shall be the duty of the Master Mechanic to keep a record of boiler washing for all steam operated cranes in both M. W. and Mechanical Department service in his territory. To this end, the Master Mechanic and Division Engineer shall cooperate in connection with cranes assigned to M. W. service.

100. Boilers used on the above equipment shall receive boiler wash and inspection at periods not exceeding thirty (30) days. Boiler washing may be made at more frequent intervals where cranes are operated in territory which so requires.

101. Certificates covering annual and semi-annual inspection, properly signed, must be posted in the cab of each crane and a signed copy of same shall be kept on file at the Master Mechanic's office.

102. Periodic inspection shall cover all mechanical details, boiler, engines, cable, cable reeving, rigging, running gear, safety appliances, locking pins, hold-downs, etc. and shall include recommendations as to repairs or alterations which may be necessary, as well as when and where such repairs or alterations are to be performed.

103. All cranes shall receive full inspection and operating test at periods not exceeding thirty (30) days (preferably at boiler wash periods). Such repairs or adjustments as may be required to place the crane in first-class working condition must be made at this time and before crane is returned to service.

104. Certificate showing condition crane is returned to service, signed and sworn to, must be posted in the cab of each machine. Copy of such certificate must be carried on file at the Master Mechanic's office.

105. Cranes out of service must be covered by out-of-service certificate in the same manner as prescribed in connection with boiler inspection.

106. It shall be the duty of each crane operator, at the beginning and at the end of tour of duty, to make inspection of the crane assigned to him to see that same is in safe and efficient working condition.

107. It shall be his responsibility, when going off tour of duty, to report all work necessary to be performed on crane for its further continuance in service.

108. For cranes in M.W. service requiring repairs or adjustments which cannot satisfactorily be made by the crane operator, arrangements shall be made by the Division Engineer with the Division Master Mechanic for such repairs or adjustments to be made by the Mechanical Department.

109. It shall be the duty of the Division Master Mechanic, or Division Engineer, to anticipate, as far as practicable, repairs or adjustments which are to be made at the periodic inspection periods, to the end that reliable crane service be afforded at all times with minimum interruption on account of emergency repairs or adjustments in the field.

110. All cranes, after having undergone general overhaul and before same are returned to service, shall be given a thorough operating test to determine working condition, capacity or general operating efficiency.

111. Under no condition shall modification to crane affecting its operation or capacity be made without approval by proper authority.

112. Where cranes have been modified at period of general overhaul to the extent that capacity ratings are affected, same shall be given capacity tests at various radii to establish safe working load ratings in conformity with those posted in cab.

113. When occasion requires the transfer of crane equipment from one Division to another, or from one Department to another, a statement shall be furnished by the Department to which crane has been last allocated covering the valuation of equipment in present condition, together with a statement covering the estimate cost of repairs necessary to place the equipment in first class condition.

POINTS FOR SPECIAL ATTENTION FOR INSPECTION OR REPAIRS

114. General cleanliness of machine is necessary in order to avoid personal hazards, fire hazards and to facilitate the inspection or repair of the machine. The crane operator will be held responsible for the general cleanliness of his machine.

DAILY INSPECTION

115. Daily inspection of cranes by operator when coming on or going off duty, shall give consideration to the following:

115. (A) Examination of all cables to see that they are in proper and safe operating condition, same to include cable clip fastenings, inspection for broken strands, kinked cable and cable lubrication.

115. (B) See that machine is properly oiled or lubricated.

115. (C) See that safety guards, locking pins, limit stops and hold-downs are in proper place and in working condition.

115. (D) See that boiler feed apparatus is in proper working condition.

115. (E) Inspect the entire machine for loose or broken parts.

115. (F) Check water in gas engine radiator.

115. (G) Check oil in gas engine crankcase.

115. (H) Lubricate generator equipment.

115. (I) Inspect commutator and brushes, cleaning and making adjustments as may be required.

115. (J) See that roller track under crane turntable is dry and free from grease.

PERIODIC INSPECTION

116. At time of periodic (30 day) inspection, the following should be included:

Boom
Cable sockets
Cable clips
Clutches
Operating levers
Crossheads
Piston packing
Propelling gear
Swing stops
Draft rigging
Frame
Car underframe
Cotter keys
Boom pins
Cable socket pins
Drums
Brakes
Cone rollers
Crosshead guides
Valve stem packing
Locking pins
Rail clamps
Brake rigging
Frame braces
Bolts
Rivets
Cables
Sheave wheels
Castings
Gears
Center pins
Connecting rods
Shaft bearings
Hold-downs
Safety appliances
Trucks
Brackets
Nuts

116. (A) Clean machinery to remove all dirt and oil. Special care should be exercised to avoid steam or water getting on electrical apparatus (using protective oil cloth or canvas over such equipment during cleaning operation).

116. (B) Check for water leaks in cylinder head, hose connections, water manifold flange, water pump and connections.

116. (C) Check hand brake to see that same operates freely without binding.

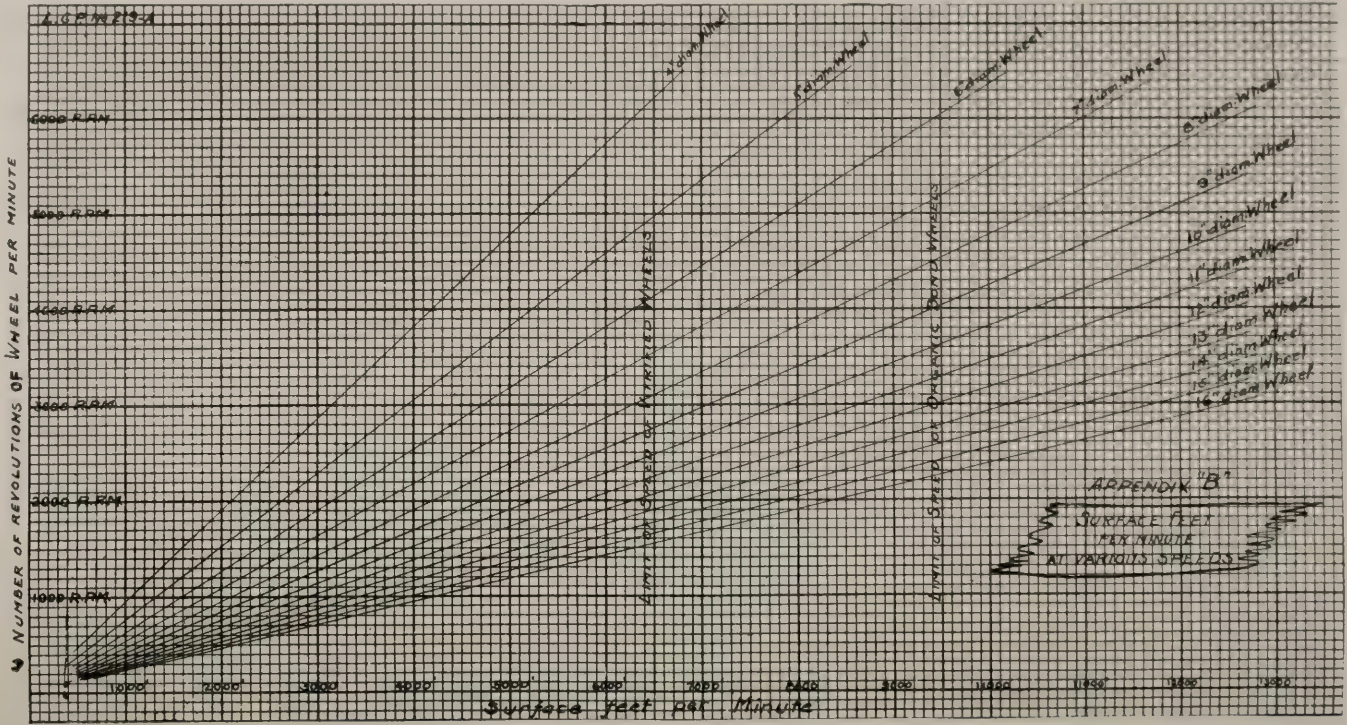
116. (D) Crank engine and test for compression.

116. (E) Inspect, clean and adjust spark plugs.

116. (F) Inspect breaker points and clean and adjust where necessary.

116. (G) Check ignition cable for breaks or leaks, replacing where necessary.

116. (H) Inspect and clean carburetor screens.



SURFACE FEET PER MINUTE AT VARIOUS SPEEDS

116. (I) Clean and oil magneto and inspect points and brushes, replacing where necessary.

116. (J) Avoid excessive lubrication of magneto (two (2) or three (3) drops of light oil for every fifty (50) hours service are sufficient).

116. (K) Check valve tappet clearance and adjust where necessary.

116. (L) Clean electrical equipment.

116. (M) Change oil in crankcase every fifty (50) working hours.

Crawler Cranes

117. All rules and instructions contained in this manual relating to machines, gasoline engines and cranes must be observed in the operation of crawler cranes.

118. The operator is responsible for the safe handling and operation of the crane on the ground, on cars and when being loaded or unloaded. When handled by a large crane, he must see that no hitches are applied in a way that is likely to damage the crane.

119. The crane must be fastened securely to avoid rotation when moved in a train on any truck. Cranes should be anchored securely to the car body by means of suitable anchorages provided at crawlers, rear end of upper works and at boom. The operator must see that, in addition to the slewing lock or locking pins being in position, suitable boom shackles are fastened to the car, or that the boom is dropped on a recessed carrier and the boom hoist cables left slack. He is responsible for having boom shackles replaced immediately when the regular equipment is lost or broken. So far as practicable, the boom must be hauled in trailing position. Boom shackles must be released before attempting to raise the boom, to prevent damage to the boom.

120. Pipes or valves are not permitted in drain connection at bottom of gasoline tanks. They are likely to be broken off when traversing rough ground, dense brush, etc. Plugs must be used in drain holes.

Cranes (Locomotive) and Ditchers

121. When heavy lifts are to be made the operator must assure himself that the crane is blocked properly and that the brakes are set.

122. If locomotive cranes are not provided with mechanical locks to prevent rotation it is particularly important to see that adequate boom shackles are provided and used. Neglecting to observe this rule may result in a serious accident.

123. Booms may be damaged by attempting to raise them before the boom shackles have been released. Where small cranes are equipped with transverse wheels, the operator is responsible for seeing that proper set-off blocking is provided before attempting to move the crane off the track.

Drills, Power Rail—Power Bonding

124. The instructions issued by the manufacturer covering these machines must be followed.

125. Care must be exercised to avoid breaking the drill bit. The bit must be firmly fastened in the chuck. The feeding pressure against the rail should be reduced just as the point of the bit penetrates the opposite side of rail. Loose bits and improper feeding are the chief causes of broken bits.

126. Dull bits must not be used, and bits must not be changed while the engine is running.

127. The proper cutting compound should be used, applied in a continuous flow.

Air-Operated Extension Side Dump Cars

128. No special operator is required for this type of equipment.

129. The supervisor to whom cars are assigned is responsible for keeping them clean and in good working order and knowing that car inspectors are maintaining the air lines and lubrication. All moving parts, including cylinders and piston rods, should be kept properly oiled or greased. Air dump cylinders should be cleaned and oiled at the same time air brake cylinders are cleaned and oiled.

130. Instructions issued by the builders with respect to dumping the cars must be observed.

131. The cars must not be loaded beyond the rated capacity.

132. Heavy loads must not be dropped into cars from such heights as will damage floor or sides.

133. Hot material must not be loaded into the cars.

134. All latches must be released before attempting to dump cars equipped with locking mechanisms.

135. When locomotives are not equipped with separate air supply line, the cars must be secured with hand brakes before the air-brake line is disconnected from the locomotive, after which the air-brake line should be connected with the supply line on the car adjacent to locomotive. The brake valve on locomotive should then be placed in full release position to obtain at least 100 lb. pressure before dumping cars.

136. Push poles must not be used for dumping or righting cars.

137. A safety chain should be available for holding the trucks to the track if a car is loaded in such a manner that it is likely to lift the wheels off of the rails as the load is being discharged.

138. When a car fails to right itself after dumping, turn the air pressure back in the dumping cylinders and clear the car of all lading, being sure that the door is clear When everything is clear of the lading, exhaust the air from the dumping cylinders and the car body will return to normal position by gravity.

139. Where cars are equipped with locking mechanisms, such as the Clark, all latches must be in place over pins after dumping and before they are to be handled in train

140. In freezing weather, drain storage reservoir frequently.

141. All defects in cars must be reported promptly to the motive power department.

Electric Arc-Welding Outfits

142. The Book of Rules, Safety Rules, and instructions previously given in this manual pertaining to machines and gas engines must be observed in the operation of these outfits, in addition to which the instructions furnished by the manufacturers of the equipment must be closely followed.

143. Welding generators must be set up as nearly level as practicable, and when in operation, must be kept clean, dry and free from dirt.

144. When the side panels are removed from the generator, they must be secured to prevent them from being picked up by the draft following passing trains. When leaving the machine at the end of the day's work, the side panels must be placed on the machine and locked securely.

145. Welders must use welding screens, not only to protect the eyes and skin from the effect of the ultra-violet rays generated by the arc, but also to protect the eyes from the minute particles of slag which fly from the surface of the weld while cooling. Hand screens and helmets must be kept in good condition and screens with cracked lenses or fibre, or that are otherwise defective, must not be used. Welders should not wear low shoes, and should at all times use the gauntlet gloves, leggings and armlets which are provided for this class of work. No part of the body which is not thoroughly covered should be exposed to the arc, otherwise painful burns similar to bad cases of sunburn are likely to result.

146. The public and others should be warned not to watch the arc, as painful injuries may result from doing so without the use of proper screens.

147. The generators should be oiled once a week and such oiling should be done when engine is not running.

148. When the generator is to be moved from one location to another on its own wheels on a track, permission to use the track or tracks that will be obstructed must be obtained, and the necessary flag protection must be provided.

149. All cables and connections must be carefully maintained; imperfectly insulated cable or connections must not be used.

Power Tools in Electrified Territory

150. Electric power must be taken from special sockets where provided, and under no circumstances shall any connection be made with any other high tension circuits or with train propulsion wires. Portable transformers are to be used with the sockets above described. From the low voltage side of the transformer cables are run to the tools to be used. Only 110-volt machines are to be employed.

151. Electric power must be taken only from specified sources and under no circumstances must any connection be made with high tension lines.

Flexible Shafts

152. Cores should be drawn out and examined at suitable intervals and oiled if necessary. In returning the core to the case, if removed for any reason, turn it until the flat portion matches the corresponding flat place in the sleeve. When shafts are not in use they should be kept in a horizontal position. Keep cores clean and free from dirt. Avoid sharp bends. When shaft begins to buckle, it is either being worked beyond its capacity or something else is wrong. Stop and investigate. A flexible shaft is a bearing throughout its entire length, and must, therefore, be kept well lubricated at all times.

Grinders

153. Flexible shaft housings stretch in use, and sometimes have to be shortened to maintain good contact between end of core and the sleeve in which it fits. Unless a removable bushing is provided for that purpose, the shortening of the housing should be done by the manufacturer. To insure proper relation between the parts, both housing and core must be sent in.

154. Proper flag protection shall be provided for the track grinders and workmen.

155. Competent men shall be assigned to the mounting, care, and inspection of grinding wheels and machines. Whenever a grinding wheel breaks, a careful inspection shall be made to determine whether the hood has been damaged, or the flanges bent or sprung out of true or out of balance. The spindle and nuts shall also be carefully inspected. After mounting a new wheel, care should be taken to see that the hood is replaced properly. All new wheels shall be run at full operating speed for at least one minute before applying them to the work, during which time the operator shall stand at one side. Cold wheels should not be forced against the work, but applied gradually, giving the wheel an opportunity to warm up and thereby minimize the chance of breakage. This applies especially to starting work on cold mornings.

156. Wheels should be tested occasionally for balance, and rebalanced if found necessary. Wheels worn out of round shall be trued by a competent man. Wheels out of balance through wear, which cannot be balanced by truing or dressing, shall be removed from the machine. Grinding on the flat sides of straight wheels is often hazardous and should not be allowed when the sides of the wheel are worn appreciably thereby, or where any considerable or sudden pressure will be brought to bear against the sides.

157. Minimum spindle diameters and maximum wheel speeds shall be governed by the Safety Code for the Use, Care and Protection of Abrasive Wheels, approved by the American Standards Association, 29 West 39th St., New York City.

158. Direction of spindle thread. Ends of spindles shall be so threaded that the nuts on both ends will tend to tighten as the spindles revolve. Care should be taken in setting up machines to insure that the spindles are mounted so that they will revolve in the proper direction, otherwise the nuts on the ends will loosen. To remove the nuts, they should be turned in direction the spindle revolves when the wheel is in operation.

159. Until a few years ago, abrasive wheels were made exclusively with silica or other vitrified inorganic bonds to hold the particles of grinding material together. Wheel speeds were limited to 6,500 surface feet per minute. Recently, the synthetic resin, Bakelite and rubber bonded wheels have been brought out and they are safe for surface speeds of 9,500 surface feet per minute, and in thin cutoff wheels, up to 15,000 or 16,000 ft. per min. This makes it imperative that diligent care be exercised to insure that the proper wheel is used on the various grinders. Manifestly, it is highly dangerous to mount a wheel which is limited to surface speed of 6,500 ft. per min. on a spindle having a much higher speed, since the wheel is likely to burst. Slow-speed wheels should be painted with a red circle, medium-speed wheels with a yellow circle and high-speed wheels with a green circle. This painting should be done as soon as the wheels are received at the storehouse so there will be no danger of mounting a slow speed wheel on a high speed shaft.

160. The grinding machine operator must not place himself in a hazardous position, nor allow any of his fellow-workmen to do so, while the grinding machine is in operation.

161. Grinding wheels absorb moisture and when left exposed to rain, dew or fog must be carefully protected, for if a portion of the wheel is exposed, it will absorb water and throw the wheel out of balance, causing excessive vibration while operating at high speeds and may result in the breaking of the wheel with perhaps a resultant personal injury.

162. Grinding wheels must never be placed on damp or wet ground even for short periods of time.

163. All *grinding wheels* must be closely inspected before mounting to make sure that they have not been injured in transit or otherwise. As an added precaution, wheels should be tapped gently (while suspended) with a light implement, such as a screwdriver. Wheels should be dry and free from sawdust when applying the test, otherwise the sound will be deadened. Organic bonded wheels do not give the same clear metallic ring as do the vitrified or silicate wheels. If they sound cracked they should not be used.

164. All *grinding machines* must be inspected each day by the operator to see that the arbors, adaptors, or other machine parts on which the wheels fit are free from wear. When signs of wear are seen, new parts must be obtained and applied.

165. The recommended speed in rpm and the tested speed in rpm will be shown on a label on each wheel by the manufacturer. Before applying a grinding wheel the grinding machine operator shall see that the recommended speed shown on the wheel is not less than the speed of the grinding machine.

166. The speed of all grinding machines must be checked daily by the machine operator, and when the speed is in excess of that shown for the particular make of machine, adjustment must be made to give the machine proper speed (see chart for surface feet per minute at various speeds.)

167. Where the speed of the wheel spindle is adjustable, speed adjustment shall be made by an authorized person only.

168. Grinding wheels must fit freely on the spindles and should not be forced on, nor should they be too loose.

169. Washers or flange facing of compressible material, such as blotting paper must be fitted between the wheel and its flanges.

170. When tightening spindle nuts, care must be taken to tighten them only enough to hold the grinding wheel firmly; otherwise the clamping strain is liable to damage the grinding wheel.

171. Some grinding machines are operated with flexible shafts. It is to be noted that some of the small portable units are driven by gasoline engines having their best and most economical speed around 1,800 to 2,000 rpm. Flexible shafts operate satisfactorily at a speed about 3,500 rpm. If engine is belt connected to countershaft in such a way as to serve as a clutch, belt should be loose when starting engine. After the engine attains the proper speed, the belt should be tightened gradually, to avoid throwing a sudden load on the flexible shaft. The inertia of the grinding wheel must be overcome and it must be brought up to speed slowly. Some flexible shafts have a gear box at the delivering end by means of which the spindle speed is multiplied by two. With this device a 6-in. grinding wheel which would normally have a surface speed of 5,500 ft. per min. on a flexible shaft turning 3,500 rpm without a gear box, would have a speed of 11,000 ft. per min. if the gear box were present in the drive. This illustrates the extreme care which must be exercised to see that grinding wheels are not overspeeded, as the flying pieces from a bursted wheel are a source of great danger to the operator and other persons or workmen in the vicinity.

172. When operating power grinding wheels, gauntlet gloves and protective glasses must be worn. The guard must be maintained in the most suitable position for the protection of the operator, and care should be taken when changing wheels not to overtighten the retaining nut. Track grinding machines must be carefully handled off and on the track, in order not to distort the guides for grinders. Over-lubrication should be guarded against in the grinding motors, where excess oil will gather particles of abrasive material and steel, and cause excessive amount of wear in the bearings.

Hilliard Portable Milling Machines

173. The instructions issued by the manufacturer must be followed.

174. For operation, this machine is clamped to the rail so that permission to use the track must be procured. It must be so clamped to rail, however, that it may quickly be removed.

175. Care must be used in feeding the cutters to rail, so as not to damage or unnecessarily dull the cutters. Overflowed metal should be chipped off the head of the rail at the starting point in order that the cutter may not have to start in this hard cold-rolled material.

176. The proper cutting compound should be used, applied in a continual flow.

Jackson Power Ballaster

177. When using or fouling tracks, permission to use the track must be procured, and the required protection must be provided.

178. The machine must be operated by qualified operators only.

179. In raising track, care must be used not to raise above the grade established.

180. All spare parts must be kept with the machine.

181. The cab must be kept locked when machine is not in use.

182. The machine is to be operated with tamping shoes ahead, otherwise the weight of the heavy portion of machine on untamped track will settle track from grade.

183. When traveling, be sure oil cups serving the clutch bearings are turned on and kept supplied with oil.

184. When traveling or not in use, and at all times except when tamping, the tamping cross-head must be locked securely at top of stroke by the cross-head latch.

185. Before operating tamping lever, the propelling lever should be in neutral position and the foot-brake applied.

186. Before operating propelling lever, the tamping lever should be in neutral position and the foot-brake released.

187. Adjustments must be made to cross-head portions of the machine only when the cross-head is locked by the cross-head latch, or when the tamping shoes and cross-head are resting on the ground and the engine gear is in neutral.

188. Block and lock the wheels of this machine securely when on setoff to prevent movement with the possibility of fouling track.

189. Check all bolts and tighten loose ones on the tamping head and tamping shoes every two hours. Check all other bolts on the machine daily and keep the cross-head slide nuts on the outside of the machine tight at all times.

Jordan Spreader

190. The general instructions pertaining to machines apply to these machines.

191. The operator of a spreader must have in his possession and thoroughly understand the book of instructions issued by the makers of the machine he is operating.

192. Spreaders are to be operated by qualified operators only. Unauthorized persons must not be permitted on the machine.

193. When it is necessary to work around the wings, braces or front plow in the open or down position, first place them in the desired position. Then either allow the wings to go down until they rest on the ground or block them securely so that there is no possible chance for them to drop or swing in.

194. Never allow any air in any cylinder supporting a part that will move, while working about the machine.

195. With Type A spreaders equipped with hydraulic locks, care must be used in filling them with oil to prevent air being entrapped in the ram. This may be done by pouring the oil into the ram slowly and entirely filling it before replacing the plug. All connections and joints of the hydraulic system must be tight.

196. When the machine is traveling over the road, even for short distances, the pins supporting the main wings and the front plow must be in their holes and the safety chains at the rear of the plow side wings must be pulled tight to prevent these parts from dropping.

197. Operator must know that proper tools, spare parts and rerailing frogs are provided. They will be held responsible for their safekeeping and for knowing that they are in safe and suitable condition for service. The operator's cabin must be locked when the spreader is not being used.

198. The operator must see that the signal whistle is kept in proper condition for use at all times.

199. Before locking the wing of Type A spreaders in any position, the bank-builder arm must be placed half way between the vertical and horizontal positions.

Madden Rail Layers

200. The rollers, wheels, chain hoist and other movable parts must be kept clean and well lubricated.

201. The machine must not be put on or off the track while the engine is running.

202. When moving the machine along the track it must not be pulled by a motor-car.

203. In laying rail, the operator must be alert to the operation, and raise the rail a sufficient height to drop it in place, using care not to raise it above that height.

204. When handling the machine with the crane, care must be used in making hitch to avoid damaging the machine.

205. The machine must be protected from the weather when not in use.

Mole Ballast Cleaners

206. The operator of a mole must have in his possession and thoroughly understand the book of instructions issued by the makers of the machine he is operating.

207. Moles are to be operated by qualified operators only. The operator must see that the mole is properly set to clear trains and special care must be exercised when it is working on curves, to take care of the differences in the elevation of the two tracks.

208. The operator must see that the proper digging points are used in the proper place as called for by the width of center ditch. When the machine starts to raise at the front end it is an indication that the digging points are worn too short or their springs are not in proper adjustment.

209. The mole should be cleaned thoroughly every night and run idle for a sufficient time to clean the belt and rear conveyor screw of dirt, after which it should be covered with the tarpaulin that is provided.

210. Drive chains should be oiled frequently.

211. The operator must see that the lubricating instructions, as shown in the Book of Instructions and lubricating charts, are followed strictly.

212. The operator is responsible for having the proper tools and for keeping them in serviceable condition.

213. So far as practicable, moles should be operated up-grade to permit water to drain away from the mole.

214. When necessary to clear approaching trains, the operator must throttle the motor down to idling speed.

Nordberg Power Jacks

215. The instructions published by the manufacturer must be followed.

216. The machines must be operated by qualified operators only.

217. In throwing or raising track care must be used not to raise it above the grade established.

218. All spare parts must be kept with the machine.

Power Track Wrench—Nordberg

219. Engine should be stopped when working on machine.

220. Rubber washers must be in place between overload release arms.

221. Clutch faces must be kept free from grease.

222. In adjusting reverse gear clutches it should be borne in mind that clutc is to REMAIN ENGAGED ONLY WHILE HELD "IN" with clutch hand lever, differing in this respect from the usual application of this type of clutch. The adjustment of yoke J–222 should, therefore, be such that links J–223 will not pass center when clutch is fully engaged and clutch will immediately release when pressure on hand lever is removed. Some adjustment of clutch forks W–275 on clutch operating shaft W–276 may also be required. The function of the clutch operating rod spring W–293 is only to take the weight of the operating parts off the clutch, thus preventing the clutch from creeping "in". This spring should be adjusted accordingly.

223. Chain should be adjusted by means of eccentric W–192 so that there is a slight slackness, but not enough so that chain will rub on frame. Chain should be kept as clean and well oiled as possible.

224. All safety guards must be kept in place when operating machine.

225. To remove hub and back plate of clutch, run off adjusting yoke and replace it with wornout yoke, applying wheel puller to wornout yoke. If wheel puller is applied to clutch cone collar the clutch links will always break.

226. Lock washers should always be used on cap screws holding overload release spring clips W–163. This will avoid breakage and looseness of clips.

227. When socket is on nut, the adjusting set screws on wrench arm should be set so that they barely clear contact with main track wrench frame. This will avoid exces-

sive buckling of wrench arm and derailing of machine. This adjustment may be necessary when changing from one weight of rail to another.

228. Operators will check machines for proper tension on nuts. This will be done twice daily, in the morning when commencing work, and at noon. Check shall be made in such manner as may be prescribed.

229. If nut will not tighten with machine in high speed forward, do not change to low speed forward, but instead go to low speed reverse and back nut off at least one full turn (or break bolt if nut is frozen); then tighten with high speed forward. This will avoid uneven tension on nuts.

230. When overload release cam W–169–A snaps past the roller W–162, clutch must be thrown out quickly before cam comes in contact with roller a second time. To permit a second "snap" throws a very severe load on the entire machine and results in broken chains, broken overload release arms and springs and causes unnecessary wear on all parts. Good operators have no difficulty in throwing out clutch before cam picks up roller the second time.

231. Both high-low and reverse clutches should be thrown in and out smoothly. Avoid abrupt movement of clutch operating handles.

232. High-low clutch should be held at just sufficient pressure to keep clutch engaged.

233. Wrench arm must not be permitted to ride the rail in moving from one joint to the next. If not desired to tighten wrench arm springs W–239 and spring chains W–240–A so that arm will swing clear of rail, the arm should be pushed to one side allowing the socket rather than the wrench arm to ride the rail.

Power Track Wrench Woolery

234. The engine of this machine is of the 2-cycle reversible type. Always retard the spark when starting the engine and *advance* it for running. This means move the timer lever 6 in. or 8 in. from the straight up position in the same direction you are going to start engine. After the engine starts move the timer lever about the same distance past the vertical in the *opposite* direction, so as to give ignition advance. There are no other adjustments to make for reversing.

235. Wipe timer face clean and oil once a day. Be sure the engine *always* has lubrication. The crankshaft is ball bearing and gets its lubrication from the oil in the gasoline.

236. Oil the governor bearings and all moving joints at least twice a day.

237. The main or head casting contains the bronze worm gear and main shaft, as well as a train of four gears on one side and three on the other. All these gears run slowly but the pressure on the bearings is enormous, for which reason it is important that they always be well lubricated. The worm housing is on top of the worm gear case and has a ½-inch pipe plug for oil.

238. If the high speed clutch begins to slip, the necessary adjustment can be made by pulling out on the spring pin and turning the spider one hole.

239. Adjustment of the low speed band requires care. It must hold to apply the desired force to the nut. When it is "off" it *must* be free so it will not drag on the drum. When the high clutch is *in,* the low drum runs at engine speed and only a little drag on this large diameter will absorb much power.

240. When making adjustments on the brake band, be very careful to see that the drum is free when the band is released.

241. Start the engine by cranking to the right to tighten nuts. To remove nuts, start the engine and then reverse it by switching off the spark until it *almost* stops; then put switch on again and advance spark for the reversed motion.

242. Adjust the set screws in the end of the frame to bring the socket wrenches or chucks to the right height to go on rail-joint nuts. Adjust balancing arm to level the machine so it will be at the right height on both sides of rail.

243. Push the machine to register with the nut and turn hand wheel to force the wrench onto the nut; push the clutch lever into high until the nut seats, then pull the lever to release high and clamp brake band and lock jointed link; let go of lever so automatic release can work. When nut reaches the degree of tightness for which the "kick-out" is set, the power releases automatically.

244. To find the correct power to apply to a nut, first tighten one with a hand wrench and then put the machine on and adjust the spring until it will kick out just as

the nut starts. The "kick-out" does not work when removing nuts. The machine may be pushed along the track in either direction.

245. Two men are required to operate the machine; one at the wheel and the other to help push it along. To remove from track to clear trains, pick off wheel, clutch lever and raising lever and roll the machine over on its back by using the balancing arm as a lever. Close vent in gas tank and carburetor before rolling it off.

246. Keep enough water in the water jacket to cover the cylinder head. The water in a hopper jacket boils under normal operation. Do not try to keep it cool; merely replenish what boils away.

Paint Sprayers

247. The instructions issued by the manufacturer for each type of sprayer and pressure paint tanks and attachments thereto must be followed.

248. Spray guns must have the movable parts oiled daily.

249. Spray guns must be cleaned at the completion of a job and at the end of the day's work. To do this remove the necessary parts, rinse or suspend them in a cleaning solvent suitable for the material used. Before using again, blow out with compressed air.

250. Do not use caustic soda or other alkali solution for cleaning aluminum parts.

251. Use good gaskets on paint tanks and draw lid clamps down tightly and uniformly to prevent air leakage (see Par. 275).

252. Strain ordinary paint through a 20-mesh screen and other paints as required.

253. Introduce air into the paint tank slowly. Sudden application of full pressure scatters paint on the interior of the lid and may clog the passages through the lid.

254. Always release air pressure on tank during periods of idleness. Do not allow safety valve to become dirty or coated with paint.

255. The life of the hose depends upon the care given it. Do not allow kinks or short loops in hose. After use, always clean the fluid hose thoroughly. Take the lid off the paint container, lift out the paint can, and put in a clean can with about 1½ pints of turpentine or turpentine substitute. Put on the lid again and operate the gun for four or five minutes. This will clean out the hose and gun and leave them in good condition for use next day.

256. State regulations governing the operation of paint sprayers must be observed.

Tie Adzers and Scorers

257. When a tie adzer or scorer is to be moved from one location to another on its own wheels on a track, the instructions pertaining to the movement of motor-cars apply.

258. Before starting the work of scoring or adzing ties, the ballast under the rail and for 12 in. on each side must be removed to a sufficient depth below the top of the ties to prevent the revolving cutters from striking stones. After the rail has been thrown out and the old tie plates removed, the ties should be swept clean to remove as much sand and dirt as possible. Broken spikes must then be driven down far enough to clear the cutters.

259. Care should be taken to see that the cutting tools are clamped firmly in position so that they will not back away from the work.

260. Safety guards must be in place and act effectively to prevent throwing chips and broken pieces of tie. Operators must wear goggles and shin guards.

261. Cutter heads on adzing machines should be adjusted carefully to bring the adzed surfaces on ties into the same plane. Readjustments of the heads is required whenever there is any change in height of the rails on which the machines are operated while adzing ties. The guide rollers on adzing machines must be properly set to gage the adzed surfaces so that the same margin appears on each side of the new tie plates after the track is gaged and rails spiked. This is particularly important on curves. The guide rollers must be raised before running over crossings, switches and guard rails.

262. Transmission belts on adzing machines should be kept tight enough to prevent undue slipping. Endless belts must not be cut and spliced.

Tie Tamper Equipment—Air

263. The operator is responsible for the safe handling and operation of air compressor on the ground or on cars, and when being loaded and unloaded.

264. When the compressor is to be shipped in a train, it must be properly located in the car and blocked securely.

265. When setting up the compressor for operation, it must be supported firmly on blocking in a level position, with the wheels clear of the ground.

266. Outfits equipped with de-railing wheels should be "lowered" to throw the derailing wheels out of contact with the derailing rails; or, if possible, one or more of the derailing wheels should be chained and locked to its rail to prevent movement of the outfit as a result of jar by passing trains or through malicious tampering by trespassers.

267. When side panels are removed from air compressors, they must be secured to prevent being picked up by the draft following passing trains.

268. A pressure of at least 80 lb. shall be carried at the compressor.

269. Not less than once a week the safety valve in the air storage tank must be tested by the gage and the pressures at which the valve opens and closes recorded on daily work report.

270. On outfits automatically regulated it is necessary to hold forcibly the pilot or auxiliary valve in the loaded position allowing the pressure to rise in the receiver until safety valve blows off. Should this not occur within a 10 per cent pressure rise above the rated pressure of the outfit (110 lb. per sq. in. on a 100-lb. per sq. in. rated outfit) either the gage or the safety valve is incorrect and both should be checked in the shops.

271. The pressure gage must bear a stamp showing the name of the shop at which it was last inspected, with the date of inspection, which must not be more than six months past.

272. All air reservoirs must be given a hydrostatic test after five years of service, and once each year thereafter.

273. These reservoirs come under the classification of non-fired pressure vessels and are covered by the Code of the American Society of Mechanical Engineers. All new reservoirs must have the ASME symbol stamped in some conspicuous place, indicating that it was designed, built and inspected in accordance with the requirements. The name or initials of the manufacturer, with the allowable maximum pressure, and his serial number, must be stamped with letters 5/16 in. high. All new reservoirs that have been built for 100 lb. pressure or less must be subjected to a hydrostatic test pressure of 50 lb. in excess of maximum working pressure before being placed in service. The annual test to be at 30 lb. above the maximum working pressure. At this time the reservoir shall be given a thorough hammer test to disclose local weakening of the sheets due to pitting or corrosion. The hydrostatic tests shall be maintained at the full test pressure for at least 10 min., during which time the reservoir should not show leakage or distortion. The date of these tests shall be stamped on the reservoir, using 5/16-in. steel stencils. When the reservoir shows leakage or distortion under hydrostatic test or shows evidence, under hammer test, of sheets being thin due to corrosion, it shall be removed from service until repaired or replaced by reservoir of proper strength. The design of all non-fired pressure vessels should be approved before orders are released for material or the fabrication started.

274. When pipe lines for distribution are not used, and air hose is connected directly to compressor, such connection must be made through the after cooler rather than direct from the reservoir, in order to protect hose from heat and oil.

275. Once a day the drain valve on the air storage tank must be opened and the water blown out.

276. At night or when shutting down for the day, the air pressure must be blown off the storage tank and pipe lines, and the valve in the gas line from the tank to the carburetor closed.

277. When leaving the machine at the end of the day's work, all tools and spare parts must be put away where they will not be stolen, and the side panels placed on the machine and locked securely.

278. A convenient field or shop check to determine the condition of 12-tool tie tamper compressors, is as follows: Provide an ordinary 2-in. cast iron pipe cap with a ⅜-in. hole drilled in the center. The edges of the hole should be chamfered or rounded off. Couple a short piece of 2-in. pipe to the air reservoir and screw the pipe cap on the end. Start the engine and check the speed with a tachometer. If the compressor can hold the gage up to 80 lb. or more per square inch, the machine can be considered in good condition. If the machine will not hold 70 lb. a study should be made to determine the cause. This test should be made once a month on all compressors in service.

Pipe Lines

279. Pipe lines should be installed in accordance with standard instructions and plans, and when on irregular ground the joints and intermediate points should be supported.

280. Pipe lines should be inspected daily by the operator, and the sound of air leaks noted and prompt repairs made. Manifolds and hose should be examined during the noon hour when the tamper tools are not in use, so that air leaks may be detected readily.

281. A daily test should be made to detect leaks in the pipe lines and possible leaking valves in the compressor. To do this shut down the machine after pumping up 100 lb. of air and note how rapidly the air pressure falls. If a loss of more than 2 or 3 lb. per min. occurs, the air valve between the air tank and pipe line should be closed and the test repeated. This will give the leakage of the compressor discharge valves separately from the air line leakage.

282. When shipping pipe lines the threads should be protected by applying old pipe fittings.

Air Tamper Guns

283. Tamper guns should be oiled before using and after every two hours of service, disconnecting the air hose from the gun for this purpose. A light engine oil should be used.

284. The operator shall inspect all nuts on the air tamper guns daily and see that they are tight.

285. If the compressor does not idle occasionally, it is an indication that air is being wasted. If the pipe and hose lines are tight, an investigation should be made and the air consumption of the tamper guns checked.

286. If a gun uses more than 23½ cu. ft. of air per min. at 90 lb. pressure, it should be sent in for repairs.

287. A Toolmeter made by the New Jersey Meter Company, Plainfield, N. J., may be used for this purpose. The scale should be graduated from 0 to 25.

288. When not in use, the tamping guns must be properly protected against theft and weather.

289. When desirable to operate tie-tamping outfits during freezing weather, alcohol should be mixed with the air at the air reservoir by a device designed for that purpose.

Tie Tamper Equipment—Electric

290. The operator is responsible for the safe handling and operation of the tie tamper outfit on the ground or on cars, and when being loaded and unloaded. When the tamper outfit is to be shipped in a train, it must be properly located in the car and blocked securely.

291. When setting up the generator for operation, it must be supported firmly in a level position. When side panels are removed, they must be secured to prevent them from being picked up by the draft following passing trains.

292. Rectifiers and controller boxes if used must be kept dry.

293. Belts should be kept reasonably tight at all times, and commutators and brushes polished.

294. Never adjust or repair the power plant while the engine is running.

295. Keep contacts tight and bright on cables. Avoid kinking and stretching cables.

296. When leaving the machine at the end of the day's work, all tools and spare parts must be put away where they will not be stolen, and the side panels placed on the machine and locked securely.

297. When in use, oil tampers every day in morning and at noon with clean engine oil.

298. When not in use, the tamping guns must be properly protected against theft and weather.

Jackson Electric Tampers

299. Where 3-phase current is used especial care must be given to see that there are no loose connections or shorts in the cable lines or motors. Any break in the line, causing single phasing, will result in serious overloading of both generator and motors. Operating under these conditions may result in heating of motor to the extent of burning out the stator coil in motor or even the armature of the generator.

300. If one motor runs hot or slow, inspect first for burned out or sticking bearings; second, see that all motor bolts, including tamper blade bolts, are tight; third, look for poor contact at connector plugs; fourth, examine motor cable for broken wires at point where cable leaves motor.

301. Poor connections can often be recognized by the burned appearance of the parts, resulting from the arcing of the current.

302. If all motors run slow, disconnect one tamper at a time in rotation. If speed picks up when one tamper is disconnected, examine that tamper and its leads for poor connection or short. If speed does not pick up on this test, examine main cable for loose connection or short, and examine generator for poor brush contacts or dirty commutator. Commutator should be cleaned with cloth moistened with kerosene, turning armature by hand. If necessary polish with fine sand paper. DO NOT USE EMERY PAPER.

303. Motors should be opened once a month and all accumulated oil and dirt wiped out. Be careful not to damage insulation on windings through striking with any hard or abrasive material.

304. Disconnect cable connections with a straight pull. "Working" the connection from side to side is likely to impair the fit of the plugs resulting in loose connections.

305. Motors should be oiled daily but only a few drops applied at each point. Avoid using too much oil.

306. Generator speed must be maintained closely to the figure shown on face plate. Voltage varies with the speed. If voltage is too high, tamper motors will run too fast resulting in unnecessary strain on parts and probability of broken blades. If voltage is too low, work will be slowed up. SPEED SHOULD BE TESTED WHILE TAMPERS ARE IN OPERATION. If speed is not right, adjust governor on engine.

306. a. General instructions pertaining to gasoline engines and other machines apply. The proper air pressure for tamping ties with the machine is 3 lb. 12 oz. It is important that this pressure should not vary. Once each month, the division maintainer must check the pressure delivered with a suitable mercury pressure gage, as recommended by the manufacturer.

Track Motor-Cars

307. Rules and instructions previously given in this book pertaining to machines and gas engines apply to motor-cars.

308. Track motor-cars must be operated in accordance with Rule 80, Book of Rules, and time-table instructions.

309. Only employees qualified after examination on train rules and safety rules governing the operation of track cars on the railroad, are permitted to operate a track motor-car.

310. The foreman of the gang using a car must assign to each member of the gang his regular place on the car and his part in putting the car on or off the track.

311. All cars must be inspected daily to determine whether wheels, axles, brakes, engines, transmission, etc., are in safe working condition. Also that the car is properly lubricated and sufficient gasoline is in the tank; that no leaks are in the fuel line.

312. No adjustments are to be made to car while in motion.

313. Brakes must be tested immediately after starting the car.

314. With free-running types of cars, all riders must be on car and properly seated before car is started.

315. With engine directly connected to axle, making it necessary to push the car to start engine, one or two men should be assigned to this work and should do the pushing from behind and jump on the car from the rear, never from the side.

316. When descending grades, the engine should be kept in gear.

317. Unauthorized persons shall not be permitted to ride on motor-cars.

318. All occupants of motor-cars must remain seated on car while it is in motion.

319. A motor-car must not be put on or taken off the track while the engine is running.

320. Operation of cars at stations, through road crossings, and all other operations, must be in accordance with the Book of Rules, Safety Rules, Timetable Instructions and other instructions issued by the Superintendent.

321. Care must be used in running motor-cars through interlocking plants, through all turnouts and on approach to switches operated by remote control to avoid accident as a result of conflicting routes being set up unexpectedly.

322. Trailers must always be pulled. Hand cars must not be attached to motor-cars.

323. Motor-cars, trailer-cars, or push-cars must not be overloaded or loaded in such manner that there is a possibility of material or tools falling off.

324. When not in service, cars must be protected as well as possible from the weather, and when left in the open must be locked.

325. In maintaining and operating cars the foreman or operator should follow the general rules already given in regard to machines and gas engines in general, paying special attention to the following:

(a) Keep car clean.
(b) Keep car well lubricated.
(c) Do not overload.
(d) Do not be continually tampering with or adjusting motor. If it is not right call the repairman of maintenance of way equipment.
(e) Do not experiment or attempt to adjust parts with which he is not familiar.
(f) Read and follow carefully instructions issued by manufacturer.
(g) Devices and attachments that have not been approved for use must not be applied to motor-cars.
(h) The seating arrangement must not be altered.
(i) Remember a motor-car is a tool assigned to make work easier for gangs and is of minor importance compared to regular assigned work of track, signal, bridge or building maintenance; and when not working properly, even after following the prescribed rules and suggestions, the trouble should be reported if not corrected and another car requested.

REPORT OF COMMITTEE XXVI—STANDARDIZATION

E. M. Hastings, *Chairman;*
H. Austill,
R. C. Bardwell,
E. H. Barnhart,
F. L. C. Bond,
J. G. Brennan,
J. V. B. Duer,
Geo. S. Fanning,
John Foley,
C. F. Ford,
C. J. Geyer,
G. A. Haggander,
C. C. Haire,
M. J. J. Harrison,
Meyer Hirschthal,
A. D. Kennedy,
C. R. Knowles,
J. A. Lahmer,
F. R. Layng,
J. M. Metcalf,
John V. Neubert,
F. L. Nicholson,
J. R. W. Ambrose,
Vice-Chairman;
Arthur Ridgway,
G. A. Rodman,
F. S. Schwinn,
J. E. Saunders,
Earl Stimson,
Dr. A. N. Talbot,
J. E. Teal,
C. H. Tillett,
A. R. Wilson,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following assignments:

(1) What AREA recommended practices should be advocated for general use on railroads. Progress report.

(2) What AREA recommended practices should be sponsored as projects for National Standardization. Progress report.

(3) Maintain contact with Standardization bodies and keep the Association informed on important matters developed by such contact. Progress report.

(1) What AREA recommended practices should be advocated for general use.—Your Committee has devoted considerable study to the matter of presenting to the Association recommended practices of the AREA that are worthy of consideration for uniform practice on all railroads. Each committee chairman was requested to make up a list of the items that had been presented to the Association by his committee for adoption and printing in the Manual which in the opinion of the committee might be presented to the Association for consideration for uniform practice on all railroads. These suggestions from the various committees were carefully reviewed by the whole committee and from the many items presented a number were selected and are offered to the Association as items worthy of consideration for adoption as uniform practice on all railroads in the interest of economy and efficiency (Appendix A).

(2) The Committee reports progress on the matter of recommended practices of the AREA that should be sponsored as projects for National Standardization but does not present at this time any such project.

(3) Maintain contact with Standardization bodies and keep the Association informed on important matters developed by such contact.—In connection with this assignment the Committee held a meeting in Philadelphia on May 6th jointly with representatives of the American Society for Testing Materials. This meeting was well attended, eighteen members of the ASTM being present and sixteen members of the AREA. The conference was addressed by C. L. Warwick, Secretary-Treasurer of the ASTM, who gave a very comprehensive outline of the purposes, organization, functions, procedure, etc. of the ASTM. Dr. Hermann von Schrenk, President of the ASTM at that time, spoke to the gathering, as did Vice-President of the AREA, A. R. Wilson.

The purpose of the joint meeting was to endeavor to bring about a closer contact between the American Society for Testing Materials and the American Railway Engineering Association so that the representatives of both associations would know more about the work of the several committees of the respective associations, the thought being to emphasize the advantage of having AREA representation on ASTM committees where the work of the two associations was parallel.

Bulletin 382, December, 1935.

After the joint conference, at an afternoon session of your Committee, the recommendation was made that the Chairman request the President and the Board of Direction of the AREA to authorize the formal appointment of members of the AREA committees for cooperative and contact work with certain ASTM committees. After full correspondence with the chairmen of the several AREA committees members were nominated, certified to the President and Secretary of the AREA (the Board of Direction having approved the plan of cooperation) and the following members of the AREA have been placed on ASTM committees:

H. H. Harman	I
W. C. Pruett	I
E. E. Chapman	IV
Robert Faries	IV
C. P. VanGundy	IV
G. J. Ray	IV
J. B. Young	IV
C. J. Hogue	VII
J. A. Newlin	VII
Theo. Doll	VIII
G. A. Haggander	VIII
Prof. W. K. Hatt	VIII
M. Hirschthal	VIII
A. C. Irwin	VIII
A. N. Laird	VIII
J. F. Leonard	VIII
R. C. Bardwell	XIII
J. J. Laudig	XIII
Dr. James Aston	XV
P. S. Baker	XV
C. H. Mercer	XV
G. H. Tinker	XV
E. B. Fulks	XVII
Dr. Herman von Schrenk	XVII

J. A. Lahmer, Special Committee on Waterproofing.

It should be stated that the ASTM was very anxious to have this cooperation and the Secretary and officers of that association express gratification that the AREA representation on their committees has been increased.

AMERICAN STANDARDS ASSOCIATION (ASA)

During the past year the American Standards Association has taken very important steps in the development of its organization in order to facilitate the handling of the many and diversified subjects that are brought before it for study and the creation of American Standards for the general benefit of industry.

As a result of extensive work and recommendations of the Joint Administrative Committee and the Committee on Procedure, the Standards Council has approved an organization providing for the departmentalization of the Association's work into industrial groups, each having a divisional committee at its head, similar to the Electrical Standards Committee, the Mining Standardization Correlating Committee, and the Safety Code Correlating Committee which have been organized for several years. The plan provides for each divisional committee to carry the name of the major industry from which its members are selected and for the grouping of the Sectional Committees doing the technical work, under the divisional committees of the industries with which their work is chiefly concerned, with proper collaboration between the committees of the various groups which may have a common interest in some elements of their work. In these respects the organization is similar to the arrangement for Committee work in the AREA, though most of the ASA divisional committees have not yet been created.

In addition to the Electrical, Mining, and Safety Code Committees the divisional committees authorized or in view are the Building Code, Mechanical, Textile, Petroleum, Chemical, Lumber and Wood Products, Ceramics, Metals, Paper and Paper Products, and Building and Construction.

An article describing the general plan of organization was published in the ASA periodical INDUSTRIAL STANDARDIZATION for May 1935.

The "Building Code Correlating Committee" already is organized with twenty-one associations as members and with Rudolph P. Miller (ASCE), of New York as Chairman, and George N. Thompson (National Bureau of Standards), Washington, as Vice-Chairman

The "Mechanical Standards Committee" is being organized. The Association of American Railroads has accepted membership and has appointed W. I. Cantley, Mechanical Engineer, Lehigh Valley Railroad, as its representative. Mr. Cantley already represents the AAR, Division V—Mechanical on the Standards Council ASA.

The formation of the "Textile Standards Committee" is under way.

The Standards Council has also authorized the organization of an "Advisory Committee on Ultimate Consumer Goods" as a medium of contact with Consumer groups as represented by National associations, distributors and governmental agencies and to advise on methods of handling specifications and labels for ultimate consumer or over-the-counter goods.

A Standard Council "Committee on Assignment of Work" has been authorized and appointed. This Committee consists of the Chairman of the Council's Board of Examination and the Chairman of all divisional correlating and advisory Committees. F. M. Farmer (ASTM), Vice-President, Electrical Testing Laboratories, New York, Chairman of the Board of Examination and Vice-Chairman of the Standards Council is Chairman of this Committee.

New "American Standards" of special importance are:

National Electrical Code—ASA Project C1—1935.
Screw Threads for Bolts, Machine Screws, Nuts and Threaded Parts — ASA Project B1–1—1935. (Revision of B1a—1924)

A complete list of "Standards Approved by the American Standards Association", period September 1, 1934 to September 1, 1935 is published as Appendix B of this report.

At the annual meeting of the ASA December 1934, J. C. Irwin (AAR) was re-elected Chairman of the Standards Council, and F. M. Farmer (ASTM) was re-elected Vice-Chairman.

The AAR members of the Board of Directors and the Representatives and Alternates on the Standards Council continue as listed in last year's report.

A complete list of ASA projects on which the Association of American Railroads is now cooperating, showing the ASA Project, the AAR Division or Section Represented, AREA Committee Contact, and the Members Representing Railway Associations is included as a part of this report as Appendix C.

CANADIAN ENGINEERING STANDARDS ASSOCIATION (CESA)

B. Stuart McKenzie, Secretary, CESA, has furnished the following memorandum of the principal activities of his Association during the year 1935:

Civil Engineering and Construction

The Association has now published under designation A 36–1935 a standard covering Dimensions for Building Brick, which it is believed fairly represents Canadian practice. An effort will be made through the technical associations and manufacturers to secure adoption of the standard, and thereafter consideration will be given to other types of building materials. The size adopted is 8⅜ × 2⅜ × 4 inches, for both face and common brick.

The first draft of a specification for Structural Timber has been submitted to a newly organized committee, and comments have been received thereon.

Mechanical Engineering

Work in this department has not been very active during the year.

A summary of comments on the first draft of the Safety Code for Passenger and Freight Elevators has been sent out and a small panel is working on a second draft.

Electrical Work

The third edition of the Canadian Electrical Code, Part I, was issued in January, 1935, and as usual special provincial editions have been prepared for some of the Provinces.

Under Part II of the Code, dealing with approval specifications, the work has continued to be very active. Specifications for Enclosed Switches, Transformers for Luminous-tube Signs and Oil-burner Ignition Equipment, Industrial Control Equipment in Ordinary Locations, Insulated Conductors for Power-operated Radio Devices, Cable for Luminous-tube Signs and for Oil-burner Ignition Equipment, Soldering Lugs, Motor-operated Blowers and Stokers, Cord Sets, Measuring and Discharge Devices for Explosive or Flammable Liquids, Automatic Motor-control Devices of Small Capacity and Auxiliary Gutters, Junction-boxes and Pull-boxes, have been published. Specifications for Electrically-heated Warming Pads, Oil Circuit-breakers, Dust-tight Enclosures, Wireways and Busways, Asbestos-insulated Stove Wire, Panelboards, Enclosed Branch-circuit Cutouts, Switchboards and Switching Equipment, Electrically-operated Refrigerating Machines, Electric Cranes and Hoists, Electrode Receptacles for Luminous-tube Signs, Low-voltage, Control-circuit Wire and Cable, and Electrical Appliances for Hair Dressing, are still in draft form but many of them have been discussed at meetings of the special Panel dealing with this subject. First drafts of Specifications for Christmas-tree and Other Decorative Lighting Outfits, Rubber-covered Wires and Cables, Cutout Bases, Cabinets and Cutout Boxes, Ground Clamps, Receptacles, Plugs and Similar Devices, Lamp Holders having Socket Screw-shells and Flexible Tubing (non-metallic), are out for comment at the present time.

Under Part III of the Code, dealing with the general subject of Outside Wiring Rules, there has been considerable activity in connection with Overhead Systems, particularly the question of railway crossings. The Association has been in close touch with the railways and communication companies and has been studying a draft set of regulations dealing with this important subject, which it is hoped to issue in tentative form very shortly. Under Inductive Coordination, a report on Definitions and Principles has been prepared, also a draft covering regulations for Radio Interference. In connection with Conductive Coordination, a report has been prepared dealing with Electrolysis and a report on Grounding has also been issued.

Under general electrical work, the Association still has under consideration a draft specification for Insulated Power Cable, and has also been considering Enamelled Magnet Wire. A committee is also considering revisions to the present specification covering Galvanized Telegraph and Telephone Wire.

Ferrous Metals

A specification covering Carbon-Steel Forgings has been issued during the year (No. G 38–1935).

Steel Construction

Under the new Sectional Committee on Steel Construction, work has continued on revised specifications for steel, and four specifications have now been issued covering Mild Steel, Medium Steel, Silicon Steel and Rivet Steel. The use of these steels will allow higher unit stresses in bridges and buildings, and committees are now studying the necessary revisions to specifications which have been issued by the Association. A panel dealing with Structural Steel Welding is at work and a report is expected shortly.

General

The reorganization of the Main Committee of the Association is proceeding and was discussed in detail at the last meeting of the Main Committee. As previously reported an effort will be made to increase representation from industry, and in this way stimulate interest in the work of the Association.

Industry has been supporting the Association financially, and there has been a slight increase this year in the receipts, which is encouraging.

The Association continues to occupy quarters in the National Research Building on Sussex Street, Ottawa."

The Committee on Standardization,
E. M. Hastings, *Chairman.*

Appendix A

TABULATION OF SPECIFICATIONS AND RECOMMENDED PRACTICES AS CONTAINED IN THE MANUAL AND SUPPLEMENTAL BULLETINS, WHICH ARE PRESENTED FOR UNIFORM PRACTICE ON ALL RAILROADS

The following items have been selected, after careful study, from the material presented to, and adopted by, the Association as standard specifications or recommended practices and printed in the Manual; for the purpose of placing before the Association membership and the railroads a number of items worthy of consideration for adoption as uniform practice on all railroads in the interest of economy and efficiency. The list is set up in numbered subdivisions conforming to standing committee numbers, with necessary references.

I—ROADWAY

ITEM	*MANUAL*	*BULLETIN*
Specifications for the Formation of the Roadway.	p 28	356 p 5; 367–8 p 7
Specifications for Metal Fence Posts	p 57	
Specifications for Standard Right-of-Way Fences..	p 61	372 pp 305, 307
Specifications for Corrugated Metal Culvert Pipe for Railroad Use		327 p 3
Specifications for Cast Iron Culvert Pipe		327 p 6
Specifications for Concrete Fence Posts		347 p 1
Specifications for Pipe Line Crossings Under Railway Tracks		356 p 6

II—BALLAST

Specifications for Stone Ballast		337 p 3; 347 p 16
Specifications for Prepared Gravel Ballast		337 p 7

III—TIES

Specifications for Cross-Ties	p 117	367–8 p 15
Specifications for Switch-Ties	p 122	367–8 p 15
Specifications for Dating Nails	p 126	
Specifications for Tie Plugs	p 132	
Anti-splitting Devices		337 pp 8, 9
Methods and Practices for Proper Seasoning of Ties, etc.		337 p 10

IV—RAIL

Standard Rail Sections		
Rail Section—R.A.-A. 90-lb.	p 141	
" " R.E. 100-lb.	p 142	
" " R.E. 112-lb.		367, p 17
" " R.E. 131-lb.		356, p 10
Standard Specifications for Open-Hearth Carbon Steel Rails	p 148	
Rail Inspection	p 152	
Specifications for Open-Hearth Steel Girder Rails of Plain, Grooved and Guard Types	p 153	

IV—Rail—Continued

ITEM	*MANUAL*	*BULLETIN*
Girder Rail Sections	p 158	
128-lb. R.E.—7A	p 159	
149-lb. R.E.—7A	p 159	
159-lb. R.E.—9A	p 160	
174-lb. R.E.—9A	p 160	
Girder Rail Joint Bars		
128-lb. R.E.—7A	p 161	
159-lb. R.E.—9A	p 161	
Drilling of Rails		367–368, p 16
Joint Bar and Assembly 112-lb. R.E. Rail		367–368, Insert p 16
Rail-Joint Assembly 131-lb. R.E. Rail		367–368, Insert p 17
Joint Bar for 131-lb. R.E. Rail		373, p 551
Standard Locations for Tensile Test Pieces and for Boring for Chemical Analyses	p 163	
Specifications for Drop Test Machine	pp 163–165	
Specifications for High Carbon Steel Joint Bars	p 166	
Specifications for Quenched Carbon Steel Joint Bars	p 167	
Specifications for Quenched Carbon Steel and Alloy Steel Track Bolts	p 170	
Design for Track Bolts		327, pp 12–17
Specifications for Spring Washers		356, pp 10–13
Rail Record Forms	pp 174–189	

V—TRACK

AREA Portfolio of Trackwork Plans	p 235	327, p 39 347, p 16 356, p 13 367–8, p 18 378, p 18
Specifications for Steel Tie Plates	p 244	337, p 18
Specifications for Wrought Iron Tie Plates	p 246	
Specifications for Malleable Iron Tie Plates	p 248	
Specifications for Soft Steel Cut Track Spikes	pp 252–254	367–8, p 21
Specifications for Steel Screw Track Spikes	pp 255–257	
Specifications for the Laying of New Track	p 259	
Plans and Specifications for Track Tools		327, p 18 347, p 17 356, p 14 367–8, p 21

VI—BUILDINGS

Specifications for Buildings for Railway Purposes	pp 288–447	Vol. 32, p 39 Vol. 33, p 18 Vol. 35, p 14

VII—WOOD BRIDGES AND TRESTLES

Specifications for Timber Piles (Treated and Untreated)	pp 469–471	356, pp 40–41
Specifications and Classifications and Grading Rules for Lumber and Timber to be Used in the Construction and Maintenance of Way Departments of Railways	pp 472–494 pp 497–535	356, pp 41–42
Specifications for Workmanship for Pile and Frame Trestles of Untreated Material to be Built Under Contract		
Specifications for Metal Details Used in Wood Bridges and Trestles	pp 465–466 pp 467–468	374, p 781
Specifications for Shingles	pp 494–497	
Specifications for Structural Oak	pp 558–560	

VIII—MASONRY

ITEM	*MANUAL*	*BULLETIN*
Specifications for Plain and Reinforced Concrete..	p 566	337, p 47 347, p 19 356, p 43

IX—HIGHWAYS

Specifications for Preparation of Track Structure, Width of Crossing and Approaches for Construction of Street Crossings Over Railway Track		367–8, p 55
Specifications for the Construction of Bituminous Crossings		
Specifications for the Construction of Rail Type of Street Crossings		367–8, p 56
Specifications for the Construction of Wood Plank Street Crossings		367–8, p 57
Highway Crossing Signs and Signals		No. 2 A.A.R.

XIII—WATER SERVICE, FIRE PROTECTION AND SANITATION

Specifications for Cast Iron Pipe and Special Castings	pp 902–907	
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STANDARDS APPROVED BY THE AMERICAN STANDARDS ASSOCIATION

Period September 1, 1934 to September 1, 1935

ASA Symbol	*Title*	*Approved as*
Civil Engineering		
A2—1934	Fire Tests of Building Construction and Material	American Standard
A9—1935	Building Exits Code	Amer. Tent. Std.
A14—1935	Safety Code for the Construction, Care and Use of Ladders	American Standard
Mechanical Engineering		
B1.1—1935	Screw Threads for Bolts, Machine Screws, Nuts and Threaded Parts	American Standard
B5.6—1935	Jig Bushings	American Standard
B7—1935	Safety Code for Abrasive Wheels	American Standard
B16el—1935	Addendum to the American Standard Steel Flanged Fittings and Companion Flanges—B16e—1932	American Standard
B17.1—1934	Shafting and Stock Keys	American Standard
B31.1—1935	Code for Pressure Piping	Amer. Tent. Std.
B33.1—1935	Hose Coupling Screw Threads for all Connections Having Nominal Inside Diameters of ½, ⅝, ¾, 1, 1¼, 1½ and 2 Inches	American Standard
B36.5—1935	Electric-Resistance-Welded Steel Pipe	American Standard
B36.7—1935	Lock-Bar Steel Pipe	American Standard
B36.8—1935	Riveted Steel and Wrought-Iron Pipe	American Standard
Electrical Engineering		
C8.12—1935	Specifications for Cotton Braid for Insulated Wires and Cables	American Standard
C15—1935	Specification for 750 Volt Direct Suspension Overhead Trolley Contact Construction	American Standard
C59.1—1935	Methods of Testing Molded Materials Used for Electrical Insulation	American Standard
C59.2—1935	Methods of Testing Electrical Insulating Oils	American Standard
C59.3—1935	Methods of Test for Resistivity of Insulating Materials	American Standard
C59.4—1935	Specifications for Rubber Matting for Use Around Electrical Apparatus or Circuits Not Exceeding 3000 Volts to Ground	American Standard
Ferrous Metallurgy		
G17.1—1934	Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service	American Standard
G17.2—1934	Alloy-Steel Bolting Material for High-Temperature Service	American Standard
G17.3—1934	Forged or Rolled Steel Pipe Flanges for High-Temperature Service	American Standard

ASA Symbol	*Title*	*Approved as*
Non-Ferrous Metallurgy		
H8—1934	Specifications for Free-Cutting Brass Rod for Use in Screw Threads	American Standard
H23.1—1934	Specifications for Copper Water Tube	American Standard
Textile Industry		
L5—1934	General Methods of Testing Woven Textile Fabrics	American Standard
Mining		
M7.2—1935	Frogs, Switches and Turnouts for Coal Mine Tracks for 70 lb. and 80 lb. Rail	Amer. Rec. Practice
Miscellaneous		
Z4.1—1935	Safety Code for Industrial Sanitation in Manufacturing Establishments	American Standard
Z4.2—1935	Specifications for Drinking Fountains	American Standard
Z4.3—1935	Specifications for the Sanitary Privy	Amer. Rec. Practice
Z11.1—1934	Abridged Volume Correction Table for Petroleum Oils	American Standard
Z11.5—1934	Cloud and Pour Points	American Standard
Z11.13—1934	Sulfur in Petroleum Oils Heavier than Illuminating Oils	American Standard
Z12.1—1935	Safety Code for the Installation of Pulverized Fuel Systems	American Standard
Z12.2—1935	Safety Code for the Prevention of Dust Explosions in Starch Factories	American Standard
Z12.3—1935	Safety Code for the Prevention of Dust Explosions in Flour and Feed Mills	American Standard
Z12.4—1935	Safety Code for the Prevention of Dust Explosions in Terminal Grain Elevators	American Standard
Z12.5—1935	Safety Code for the Prevention of Dust Explosions in Wood Working Plants	American Standard
Z14.1—1935	Drawings and Drafting Room Practice	American Standard
Z21.10—1935	Approval Requirements for Gas Water Heaters	American Standard
Z21.18—1934	Listing Requirements for Domestic Gas Appliance Pressure Regulators	American Standard
Z21.20—1935	Listing Requirements for Automatic Devices Designed to Prevent Escape of Unburned Gas	American Standard
Z21.21—1935	Listing Requirements for Automatic Main-Gas Control Valves	American Standard
Z21.22—1935	Listing Requirements for Relief and Automatic Gas Shut-Off Valves for Use on Water Heating Systems	American Standard
Z21.23—1935	Listing Requirements for Water Heater, Gas Range and Space Heater Thermostats	American Standard
Z21.24—1935	Listing Requirements for Semi-Rigid Gas Appliance Tubing and Fittings	American Standard
Z22.1—1935	Dimensional Standards for 16 mm Motion Picture Film and Equipment	American Standard
Z33—1935	Fire Protection Code for Blower and Exhaust Systems	American Standard
Commercial Standards		
CS49—35	Chip Board, Laminated Chip Board, and Miscellaneous Boards for Bookbinding Purposes	American Standard
CS50—34	Binders Board for Bookbinding and Other Purposes	American Standard
CS51—35	Marking Articles Made of Silver in Combination with Gold	Amer. Rec. Practice

Appendix C

AMERICAN STANDARDS ASSOCIATION TECHNICAL PROJECTS ON WHICH THE ASSOCIATION OF AMERICAN RAILROADS IS NOW COOPERATING

	ASA Project	*AREA (Const. & Maint. Sec.) Committee Contact*	*Members Representing Railway Associations*
A1	Portland Cement, Specifications for	IV Eng.—Com. VIII—Masonry	Meyer Hirschthal J. F. Leonard J. J. Yates
A21	Cast Iron Pipe and Special Castings, Specifications for	IV Eng.—Com. XIII—Water Service, Fire Protection and Sanitation	C. R. Knowles Alt. C. P. VanGundy
A22	Walkway Surfaces, Safety Code for	IV Eng.—Com. VI—Buildings	W. T. Dorrance
A35	Manhole Frames and Covers	I Oper.—T. & T. Sec. IV Eng.—Com. XIV—Yards and Terminals	J. A. Jones H. L. Ripley Alt. J. R. W. Ambrose Alt. W. T. Dorrance

	ASA Project	*Committee Contact AAR Div. or Sec. Represented*	*Members Representing Railway Associations*
A36	Rating of Rivers	IV Eng.—Elec. Sec.	R. J. Needham
B1	Screw Threads, Standardization and Unification of	IV Eng.—Com. V—Track Sig. Sec. V Mech.	J. V. Neubert H. G. Morgan W. I. Cantley Alt. S. S. Riegel F. M. Waring
B3	Ball and Roller Bearings	V Mech.	W. I. Cantley Alt. S. S. Riegel F. M. Waring
B4	Cylindrical Parts and Limit Gages, Allowances and Tolerances for	V Mech.	W. I. Cantley F. M. Waring Alt. S. S. Riegel
B16	Pipe Flanges and Fittings	IV Eng.—Com. XIII—Water Service, Fire Protection and Sanitation Elec. Sec. Sig. Sec. V Mech.	C. R. Knowles J. V. B. Duer E. K. Post W. I. Cantley Burton P. Flory
B18	Bolt, Nut and Rivet Proportions	AAR Rail Com. IV Eng.—Com. V—Track Com. XV—Iron and Steel Structures V Mech.	J. V. Neubert Alt. J. B. Myers P. G. Lang, Jr. Alt. O. E. Selby J. McMullen G. B. Smith
B20	Conveyors and Conveying Machinery, Safety Code for	IV Eng.—Com. XXIII—Shops and Locomotive Terminals	Vacant
B27	Plain and Lock Washers	IV Eng.—Com. V—Track V Mech. VI Purchases and Stores	E. W. Caruthers A. H. Fetters H. A. Hoke E. D. Toye Alt. A. G. Follette
B30	Cranes, Derricks and Hoists, Safety Code for	IV Eng.—Com. XII—Rules and Organization	W. C. Barrett Alt. M. M. Backus
B32P	Wire and Sheet Metal Gages	I Oper.—T. & T. Sec. IV Eng.—Sig. Sec.	J. A. Jones H. G. Morgan
B33	Hose Coupling Screw Threads	IV Eng.—Com. XIII—Water Service, Fire Protection and Sanitation	W. L. Curtiss Alt. J. P. Hanley
B36	Dimensions and Materials of Wrought Iron and Wrought Steel Pipe and Tubing, Standardization of	IV Eng.—Com. XIII—Water Service, Fire Protection and Sanitation V Mech.	J. J. Laudig Alt. W. B. Nissly F. M. Waring
B40P	Pressure and Vacuum Gages, Specifications for	V Mech.	F. M. Waring
B41	Stock Sizes and Lengths for Iron and Steel Bars, Including Flats, Squares, Rounds and other Shapes.	V Mech.	H. G. Burnham
B42P	Leather Belting, Specifications for	VI Purchases and Stores	C. L. McIlvaine
B43P	Machine Pins, Dimensions of	V Mech.	A. H. Fetters H. A. Hoke
C1—1935	Electric Wiring and Apparatus in Relation to Fire Hazard, Regulations for (National Electrical Code)	IV Eng.—Elec. Sec.	I. V. Goodman Alt. G. L. Sealey
C2—1927	National Electrical Safety Code Parts I and III	I Oper.—T. & T. Sec. IV Eng.—Const. & Maint. Sec. Elec. Sec. Sig. Sec.	G. R. Stewart G. I. Wright J. V. B. Duer Alt. L. S. Wells F. W. Bender Alt. B. J. Schwendt
C2—1927	National Electrical Safety Code—Continued Parts II and IV	I Oper.—T. & T. Sec. IV Eng.—Const. & Maint. Sec. Elec. Sec. Sig. Sec.	H. A. Shepard G. I. Wright J. V. B. Duer B. J. Schwendt Alt. F. W. Bender
C5	Lightning, Code for Protection Against	I Oper.—T. & T. Sec.	J. L. Niesse

	ASA Project	*AAR Div. or Sec. Represented AREA (Const. & Maint. Sec.)*	*Members Representing Railway Associations*
C8	Wires and Cables, Insulated (Other than Telephone and Telegraph)	IV Eng.—Elec. Sec. Sig. Sec.	Vacant J. J. Corcoran
C8k2—1932	Heat Resisting Wires	IV Eng.—Elec. Sec.	J. L. Bracken
C10—1924	Symbols for Electrical Equipment of Buildings	IV Eng.—Elec. Sec.	Vacant
C11—1927	Hard Drawn Aluminum Conductors	IV Eng.—Com. X—Signals and Interlocking Elec. Sec.	W. H. Elliott K. H. Gordon
C16	Radio	I Oper.—T. & T. Sec.	A. R. Belmont
C18—1930	Dry Cells and Batteries, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Sig. Sec.	G. R. Stewart A. B. Himes
C29	Insulators for Electric Power Lines	IV Eng.—Elec. Sec. Sig. Sec.	G. I. Wright G. W. Chappell
C34	Mercury Arc Rectifiers	IV Eng.—Elec. Sec.	G. I. Wright
C35	Rotating Electrical Equipment for Rail-Railway Cars and Locomotives	IV Eng.—Const. & Maint. Sec. Elec. Sec.	Sidney Withington Alt. J. V. B. Duer J. E. Sharpley Alt. W. S. H. Hamilton
C37	Power Switchgear	IV Eng.—Elec. Sec.	S. R. Negley
C39	Electrical Measuring Instruments	IV Eng.—Elec. Sec.	C. J. McCarthy
C42	Definitions of Electrical Terms	IV Eng.—Elec. Sec.	J. H. Davis
C44—1931	Rolled Threads for Screw Shells of Electric Sockets and Lamp Bases	IV Eng.—Elec. Sec. V Mech.	H. G. Morgan O. M. Bixby
C50	Rotating Electrical Machinery	IV Eng.—Elec. Sec.	J. V. B. Duer
C52	Electric Welding Apparatus	IV Eng.—Const. & Maint. Sec.	Lem Adams
C57	Transformers	IV Eng.—Elec. Sec. I Oper.—T. & T. Sec.	S. R. Negley W. A. Moore
C59	Electrical Insulating Materials in General	IV Eng.—Sig. Sec. V Mech.	E. B. Smith Alt. W. F. Zane C. R. Troop
C60P	Vacuum Tubes for Industrial Purposes, Standardization of	IV Eng.—Elec. Sec.	J. V. B. Duer Alt. A. D. Whamond
G8	Zinc Coating of Iron and Steel, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Com. I—Roadway Com. XIII—Water Service, Fire Protection and Sanitation	J. A. Jones W. C. Pruett Alt. H. H. Harman J. J. Laudig Alt. C. P. VanGundy
H4—1928	Soft or Annealed Copper Wire, Specifications for	I Oper.—T. & T. Sec.	J. A. Jones
H14—1929	Hard-Drawn Copper Wire, Specifications for	I Oper.—T. & T. Sec.	J. A. Jones
H15	Medium Hard-Drawn Copper Wire, Specifications for	I Oper.—T. & T. Sec.	J. A. Jones
H16—1928	Tinned Soft or Annealed Copper Wire for Rubber Insulation, Specifications for	I Oper.—T. & T. Sec.	J. A. Jones
M7	Coal Mine Tracks, Signals and Switches	IV Eng.—Com. V—Track	C. J. Geyer
M26P	Clean Bituminous Coal, Specifications for	VI—Purchases and Stores	C. E. Smith
O3—1926	Cross-ties and Switch-ties, Specifications for	IV Eng.—Com. III—Ties	John Foley
O4	Wood, Methods of Testing	IV Eng.—Com. VI—Buildings	W. T. Dorrance Alt. J. W. Orrock
O5	Wood Poles, Specifications for	I Oper.—T. & T. Sec.	J. A. Jones Alt. H. A. Shepard
Z2	Heads, Eyes and Respiratory Organs of Industrial Workers, Safety Code for the Protection of	IV Eng.—Elec. Sec. I Oper.—Medical and Surgical Sec.	Paul Lebenbaum E. V. Milholland
Z4	Industrial Sanitation, Safety Code for	I Oper.—Medical and Surgical Sec.	R. C. Bardwell
Z5P	Ventilation Code	IV Eng.—Com. VI—Buildings V Mech.	W. T. Dorrance Alt. W. J. Madden

	ASA Project	*AREA (Const. & Maint. Sec.) Committee Contact*	*Members Representing Railway Associations*
Z10	Letter Symbols and Abbreviations	I Oper.—T. & T. Sec. IV Eng.—Sig. Sec. Elec. Sec.	Alt. A. H. Johnson E. K. Post Alt. H. G. Morgan J. V. B. Duer
Z14	Drawings and Drafting Room Practice (Exclusive of Architectural Drawings) Standards for	IV Eng.—Com. XI—Records and Accounts	D. L. Avery
Z15	Graphic Presentation, Standards for	I Oper.—T. & T. Sec. IV Eng.—Com. XI—Records and Accounts Sig. Sec.	L. A. Moll D. L. Avery H. G. Morgan
Z16	Methods of Recording and Compiling Accident Statistics, Standardization of	I Oper.—Safety Sec.	T. H. Carrow
Z23	Sieves for Testing Purposes, Specifications for	IV Eng.—Com. VIII—Masonry	Meyer Hirschthal
Z26P	Specifications and Methods of Test for Safety Glass	IV Eng.—Const. & Maint. Sec.	J. B. Young
Z28	Standard Code for Work in Compressed Air	I Oper.—Medical and Surgical Sec. IV Eng.—Com. VIII—Masonry	J. McCombe J. J. Yates
....	Petroleum Products and Lubricants	IV Eng.—Const. & Maint. Sec.	Wm. Elmer Sidney Withington
....	Electrical Standards Committee		

REPORT OF COMMITTEE XXV—WATERWAYS AND HARBORS

*A. P. Wenzell, *Chairman;*
D. J. Brumley,
M. F. Clements,
J. P. Cronin,
A. F. Crowder,
Benjamin Elkind,
W. D. Faucette,
R. A. Feldes,
I. W. Geer,
G. F. Hand,
W. E. Hawley,
G. P. Palmer, *Vice-Chairman;*
J. R. Hickox,
N. D. Hyde,
C. S. Kirkpatrick,
P. G. Lang, Jr.,
Shu-t'ien Li,
H. S. Loeffler,
R. J. Middleton,
F. E. Morrow,
W. G. Nusz,
B. H. Prater,
E. H. Roth, *Vice-Chairman;*
G. J. Ray,
A. N. Reece,
H. F. Sharpley,
G. R. Smiley,
C. U. Smith,
A. B. Stone,
W. C. Swartout,
Edwin F. Wendt,
J. E. Willoughby,
S. L. Wonson,
R. C. Young,
Committee.

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* Died September 22, 1935.

To the American Railway Engineering Association:

Your Committee presents its report on the following subjects:

(1) Revision of Manual. The Committee recommends that the specifications for the construction of the several types of river bank protection in common use, as shown in Supplement to the Manual, Bulletin 379, page 92, be deleted; that the definitions of terms, as given in Appendix B, be deleted; that the resolution which appears in Appendix D be adopted and published in the Manual (Appendix A).

(2) Definitions of terms (Appendix B).

(3) Suitable types of construction for levees, dikes and mattresses for use under varying service conditions, giving consideration to stream alinement, sub-surface soil, or other local conditions and common use. The Committee recommends that this report be received as information (Appendix C).

(4) Types of breakwaters, bulkheads, jetties and seawalls, giving cross-sections of each and stating purpose which they serve, including comparisons of first cost, service life and maintenance cost of the various types. Progress in study—no report.

(5) Types of warehouse piers, coal piers, car float piers and others on the Great Lakes and seacoast suitable for use under varying conditions, including comparison of first cost, service life and maintenance cost of the various types, collaborating with Committees VI—Buildings and XIV—Yards and Terminals. Progress in study—no report.

(6) Size and depth of slips required for various traffic conditions, including cost of construction and maintenance. Progress in study—no report.

(7) Economic principles involved in clearances over navigable waterways. It is recommended that the report be received as information (Appendix D).

It is recommended that the resolution appearing in Appendix D be adopted and published in the Manual.

(8) Cost to railways for construction, maintenance and operation of bridges over navigable waterways. It is the recommendation of your Committee that the questionnaire be approved as to form, but not for publication in the Manual (Appendix E).

The Committee on Waterways and Harbors,
G. P. Palmer, *Acting Chairman.*

Bulletin 382, December, 1935.

Colonel Andrew Perry Wenzell

Andrew Perry Wenzell, Special Engineer, New York Central Railroad, and Chairman of this Committee, died September 22, 1935.

Col. Wenzell was born at Detroit, Mich., on August 20th, 1886. Following his graduation from the University of Michigan, he entered the service of the Pere Marquette Railway, and later was with the Grand Trunk Pacific; Pittsburgh, Binghamton & Eastern Railway, Canadian Northern Railway, and Canadian Pacific Railway.

He then organized and operated the Wenzell Construction Company from 1914 to 1921, except during the period of the World War when he was in military service. From 1921 to 1927, he was Special Engineer for the Michigan Central Railroad in Chicago, later being transferred to the New York Central Railroad in a similar capacity.

In April, 1917, he was commissioned Captain at Fort Sheridan, Ill. July, 1917, embarked for the AEF as Captain of Company F, 16th Engineers.

In June, 1918, promoted to rank of Major same regiment as commanding officer first battalion, construction of double-track cutoff at Nevers, connecting two important main lines to expedite transfer of supplies and troops by railway.

January, 1919, promoted to Lieutenant-Colonel, and assigned as second in command of the 16th Engineers.

He was discharged in June, 1919, with the rank of Lieutenant-Colonel.

Col. Wenzell was admitted to membership in the American Railway Engineering Association in June, 1927, and was a member of the Committee on Yards and Terminals from 1929 to 1933 inclusive, and later became a member of the Committee on Waterways and Harbors as Vice-Chairman, and in 1935 was elected Chairman.

Col. Wenzell was appointed a member and Secretary of the Special Committee on Inland Waterways and Intercoastal Canals and also has been a member and Secretary of the Calumet Sag Channel Committee since its inception.

He contributed freely of his time and talents to the preparation of reports of the Committees on Yards and Terminals and Waterways and Harbors. His associates will greatly miss the inspiration of his high integrity, fine character and kindly personality, and tender their profound sympathy to his family in their bereavement. In his death, the Association has lost an esteemed and valued member.

Appendix A

(1) REVISION OF MANUAL

G. P. Palmer, Chairman, Sub-Committee; W. G. Nusz, E. H. Roth, W. C. Swartout, J. E. Willoughby.

Your Committee recommends the deletion of the Specifications for the Construction of the Several Types of River Bank Protection in Common Use, as shown in Supplement to the Manual, Bulletin 379, page 92.

Your Committee further recommends that the definitions of terms shown in Appendix B be deleted.

Appendix B

(2) DEFINITIONS OF TERMS

W. C. Swartout, Chairman, Sub-Committee; W. D. Faucette, W. E. Hawley, W. G. Nusz.

During the past year, this Sub-Committee has given the list of "Definitions of Terms" adopted by the Association at the 1935 Convention and found in Bulletin 379, "Revisions and Additions to the Manual" beginning on page 87, its most careful consideration. The object which has been kept in mind is to retain in the forthcoming revised Manual only definitions of words or terms, the meaning of which is not clearly established or has a peculiar meaning when applied to the subject-matter of reports submitted by the Committee on Waterways and Harbors.

Bank, Concave
— Convex
— Sloughing
Barge
— Self-Propelled
Batter Pile
Beach
Boat
Breakwater
Brush
Bulkhead
Canal
— Boat
Cane
Cargo Track
Clearance, Horizontal or Lateral
— Vertical
Craft
Dam
Dock, Dry
Draft (of boats)
Dredge
— Clamshell
— Dipper
Dredge
— Grapple
— Ladder
— Orange Peel
— Sea Going Hopper
— Spuds
— Suction or Hydraulic
Erosion
Freeboard
Furrowed
Harbor
Impervious Earth
Jetty
Launching Ways (1)
Levee, Hydraulic Fill
— Section
— Slope
Lock
Mattress, Basket Woven
— Board
— Brush and Weaving Pole
— Brush, Pole and Fascine
— Concrete Articulated
— Concrete Slab
Navigate
Navigation
Passing Basin
Pervious Stratification
Pier (1)
— Private
— Public
Porous or Pervious Earth
Reef
Right-of-Way
Riprap
River Boat
Riverwater Gage
Sediment
Seepage
Seep Water
Ship
Shoal
Silting
Soundings
Tariff, Freight
Toll, Waterway
Tug
Vessel

Appendix C

(3) SUITABLE TYPES OF CONSTRUCTION FOR LEVEES, DIKES AND MATTRESSES FOR USE UNDER VARYING SERVICE CONDITIONS, GIVING CONSIDERATION TO STREAM ALINEMENT, SUB-SURFACE SOIL, OR OTHER LOCAL CONDITIONS AND COMMON USE

S. L. Wonson, Chairman, Sub-Committee; A. F. Crowder, J. R. Hickox, R. J. Middleton, A. N. Reece, H. F. Sharpley.

The Committee has previously submitted information on this subject and now offers a final report upon the subdivision "levees".

A levee is an embankment or wall along the bank of a stream or the shore of a body of water, built to protect land and property against inundation or overflow. A sea wall is in the general sense a levee. The type of sea wall is usually influenced by the factor of wave action to a much greater degree than is the type of river levee. Types of sea walls form a part of another report of this Committee and this report deals primarily with river levees.

The construction of embankments for protection against river floods dates from ancient times and undoubtedly accompanied the evolution of the agricultural or fixed type of society in the fertile alluvial valleys of Asia, Europe and northern Africa. In the United States the first levee was built at New Orleans shortly after its founding by the French in 1717. This levee, completed in 1727, was 5400 feet long, 3 to 4 feet high and 18 feet wide on top, the crown being used for a road. It is along the main stem of the Mississippi and along the lower sections of its major tributaries in the alluvial valley that the design and construction of levees in this country has met its greatest difficulties and reached its greatest development.

The first phase of levee development in the alluvial valley, extending from 1717 to 1882, is marked by the uncoordinated activities of individual land owners, local associations, counties and States, each building solely from the viewpoint of local protection and without consideration of the regimen of the river as a whole. In 1858, when the first phase reached its maximum development, there existed a fairly continuous line of what would now be regarded as weak, low levees from Cairo, Illinois, to 45 miles below New Orleans. Although considerable deterioration of the system occurred during the next twenty-four years, the beginnings of a national consciousness of the problem are found in the swamp land acts of 1849 and 1850 and about the same time there occurred the first studies of probable flood heights and the first efforts to coordinate and standardize levee construction.

The second phase of development, starting in 1882, is marked by the participation of the United States, acting through the Mississippi River Commission, created by Act of Congress in 1879, in the design, supervision and cost of the Mississippi levee system. This phase is concerned primarily with the creation of a primary line of defense along the main stem and the lower sections of the major tributaries, and will be complete if and when the works shall have been finished and tested by a flood greater than any of record.

In the alluvial valley and delta of the Mississippi from Cape Girardeau, Mo., to the head of the Passes, there were, as of 1931, 1830 miles of levee under the jurisdiction of the Commission and this mileage is being increased from year to year.

Types

Levees are built of earth, concrete, masonry, loose rock filled with earth, steel sheet piling, or timber. The earth embankment is decisively superior to all other types in economy and in its adaptability to raising or strengthening; in magnitude and importance it is predominant to the extent that all other types are relatively insignificant. Concrete wall levees are used primarily at locations where property development is such that the space required for an embankment is not economically available.

Location

Location is determined by—

(a) The necessity of sufficient width between levees (or between a levee and high ground on the opposite side of the river), to carry the anticipated flood discharge at its confined elevation.
(b) The space economically available for levee purposes.
(c) The desirability of leaving minimum areas unprotected outside the levee.
(d) The necessity of leaving an adequate fore shore between the levee and an unstable river bank.
(e) The desirability of avoiding abrupt changes in direction.
(f) Where practicable, the selection of a favorable foundation.
(g) The probable location of borrow pits.

Along the main stem of the Mississippi there are hundreds of miles of unstable bank. Where other considerations do not determine levee location, it is customary to so locate the levee that it will be undisturbed by loss of bank for at least 30 years. It is in general much more economical to rebuild the levee in a set back location than to stabilize the bank with revetment.

If the nature of the foundation and of the material available for construction is not known sufficiently for the purpose, it must be developed by borings.

Design

The design of the earth levee cross-section has been developed largely by experience. The essential objectives are—

(a) a height sufficient to prevent overtopping.
(b) a base width sufficient to protect against destructive foundation seepage.
(c) a cross-section sufficiently massive to protect against destructive seepage through the embankment.

The attainment of these objectives is influenced by—

(a) foundation conditions.
(b) character of available material.
(c) methods of construction.

In certain cases the design also covers—

(a) protection against wave wash and erosion.
(b) cutoff of foundation seepage.

Where flood data are inexact, as is usually the case, an additional factor is adaptability to enlargement after construction.

The two types of cross-section commonly used are the trapezoidal and the banquette; the latter being a trapezoid buttressed on the landward side by a lower and additional section.

European levees usually carry roadways on the crown, and the crown being wider than required for purely levee purposes, the slopes are relatively steep. In this country the levees in general do not carry roads, the crowns are narrower and the slopes flatter.

Up to 1890 the trapezoidal section was generally used in the Mississippi Valley. The banquette section was adopted as standard by the Mississippi River Commission in 1896 and discarded for the lower river in 1928. The present standard sections for the river below Cape Girardeau are—

Section	*Crown (feet)*	*River side slope*	*Land side slope to contain seepage line of*	*Governing material*
A	10	3–1	6–1	75 per cent or more buckshot
B	10	3.5–1	6.5–1	Loam
C	12	5–1	8–1	75 per cent or more sand

The seepage line is assumed to start 1 foot below the crown on the river side slope.

For a levee of average height, 21 feet; the B Section (loam being the predominant material) contains about 431,000 cubic yards per mile, exclusive of shrinkage.

For the upper river (above Cape Girardeau) a less massive section is adequate and the sections used approximate the standard of 1914 which is—

crown, 8 feet (above mouth of Missouri, 6 feet)
river side slope, 3–1
land side slope, 3–1 to banquette
banquette, 5 to 8 feet below crown
  20 to 40 feet wide
  top slope 10–1
  rear slope 4–1

The determination of height is perhaps the most difficult feature of design. It naturally depends upon the magnitude of the greatest flood discharge that may or can occur and also involves a determination of the increased elevation of the flood plane confined by levees, as compared with the flood plane under existing conditions of confinement. An allowance must also be made for the lack of parallelism in flood planes due to varying conditions of flood sequence and of channel conditions. Along the lower Mississippi these factors produce, for floods of equal volume, stage variations of around three feet.

In general we do not have in this country authentic stream records over a sufficient period of years to determine the maximum probable or maximum possible flood of the future. The matter must therefore be approached by a study of rainfall, runoff and synchronization of the discharge of tributaries, if any.

After deciding upon the elevation of flood plane to be protected against, it is necessary to provide a freeboard or additional elevation of levee top as a factor of safety against the uncertainties of the flood height determination and also to prevent damage by wave wash, which may so impair the levee top as to initiate overtopping and failure.

In general, freeboards of from 2 to 5 feet are customary, being increased to 6 or 7 feet in locations where conditions are unusual. Up to 1928, a freeboard of 3 feet was generally used by the Mississippi River Commission, increased, however, at centers of population where a levee failure would be particularly disastrous.

In its report of 1927, following the flood of that year, the Commission recommended that under a plan of flood protection which relied solely upon levees, the general freeboard be increased to 5 feet. In the Mississippi Flood Control project authorized by the Act of 1928 the freeboard is 1 foot, this amount then being deemed adequate in view of works other than levees included in the project for the control of major floods.

The line of seepage in the levee section is taken as starting at the assumed maximum flood level on the riverside slope. Its angle of slope through an earth levee varies with—

(a) The expected flood duration, which may vary from a few days to several months.

(b) The nature and homogeneity of the material in the levee.

The determination of lines of seepage through levee sections has been developed over many years of experience and experiments. In the great hydraulic laboratory at Vicksburg, authorized by the Flood Control Act of 1928, experiments upon this subject are being continued.

Adequate protection of the riverside slope against seepage is rarely practicable or economical. A cutoff wall, as of concrete or sheet piling, may be provided within the levee section; but in such case the wall constitutes the true levee and the embankment serves as support and protection. The use of core walls of selected, impervious and compacted material is not suitable for earth levee construction, both because it is generally economically impracticable and also because it is contrary to the fundamental necessity of homogeneity and avoidance of planes of weakness.

Foundation seepage varies with the nature of the underlying ground, the height of the flood above the area protected and, to some extent, depends upon the silt content of the flood water.

It may be intercepted by sheet piling, but at an expense generally prohibitive. The more general methods of control are, first, the loading of the ground surface adjacent to the levee, usually by a wide, low berm on the landside, and second, the provision of sub-levees forming loops or enclosed areas behind the front line levee, so as to reduce the difference in head to the point where erosive flow through the foundation does not occur.

In general, wave wash is only moderately erosive; breaking waves may also saturate the crown and landside slope. In special cases, wave fences and slope protection have been used. The best protection is an adequate freeboard.

Erosion of the levee section occurs primarily along exposed lines and at projecting angles. It may be prevented by facing the riverside slope with a resistant material, or more commonly, and generally more economically, by the provision of spur levees projecting out from the main levee line a sufficient distance to deflect erosive currents. The outer ends of these spur levees are protected by concrete or riprap paving if not otherwise naturally protected, as by timber growth.

Where the levee line is sufficiently retired from the river bank to permit a natural or induced growth of trees, brush or other heavy vegetation, flood velocities along the levee front will be so reduced that erosion will not usually occur.

Material

For an earth levee a cohesive, dense and practically impermeable material is highly desirable. Clay is the most adequate material and is improved by a moderate proportion of gravel or sand provided the particles are not too small or water worn.

While the use of selected material may be deemed economic or advisable in certain small, isolated projects, in nearly all cases, and substantially without exception for major projects, practical considerations require use of the material at hand.

Foundations

In the alluvial valley of the Mississippi experience has developed a more or less standard practice in the preparation of levee foundations; this practice embraces substantially all, and in some cases more, than is required at other and less difficult locations.

The entire base area and an additional strip about five feet wide on each side is cleared, grubbed and plowed and logs, stumps, roots and other vegetable material removed; tap roots over 1½ inches in diameter are removed to a depth of six feet. Cypress stumps, under certain conditions, are allowed to remain.

An inspection or muck ditch, commonly 6 feet deep, 6 feet wide at top and 4 feet wide at bottom, is dug along or parallel to and near the center line. All logs and other vegetable material revealed by this ditch are removed and the ditch is then back filled with levee material.

Sloughs, old pits, ditches or depressions within specified distances of the levee base are commonly filled to the natural ground level.

The levee location should be fixed in the light of a knowledge of foundation conditions, ascertained by borings or otherwise, but as a practical necessity sections of levee must frequently be built at locations where the ground is not capable of supporting the weight of the levee without displacement. In such cases compression or movement of the foundation occurs and causes subsidence of the levee.

Experience has evolved two remedies for this difficulty, which may be used separately or in combination; first, after the movement has ceased, placement of additional material in the levee section, continued until the foundation has been compressed to a state of relative stabilization; second, the construction of a wide berm or banquette on one or both sides of the true levee section, the banquette being of sufficient width and weight to counterpoise that part of the weight of the levee proper that is producing foundation movement.

Construction

Landside borrow pits are generally avoided because they, in effect, increase the height of the levee and invite foundation seepage. In Mississippi River practice the borrow pit is located at least 40 feet from the base of levee (20 feet above the mouth of the Missouri) and is excavated only to a relatively shallow depth, not exceeding 3 feet along its inner edge; the permissible transverse slope of the bottom of the pit varies from 1 in 50 to 1 in 10, depending upon location and nature of material.

To prevent destructive high water currents, traverses, about 14 feet wide on top and cut through for ordinary drainage, are left across the pit at specified intervals.

Whatever the nature of the material may be, the general requirement is that it be clean; consequently borrow pits are cleared and grubbed and all vegetable or other perishable material discarded.

Types of equipment used for earth levee construction have evolved from digging and placement by man power, through wheelbarrows, slips, scrapers and wagons to the mechanized equipment required to handle large quantities in the intervals between yearly high water periods. This equipment comprises—

Trucks or tractors and trailers, served by elevating graders or drag lines.
Narrow-gage railways,
Drag lines,
Tower machines,
Hydraulic dredges.

To function in wet weather and on moderately soft ground, trucks, tractors and trailers must have crawler treads. Narrow-gage railways require spreading or rehandling the material; although considered capable of economical and satisfactory long haul work, they are not widely used. Drag lines are commonly worked in multiple; on large levee sections tower machines are frequently worked in pairs and sometimes in groups of three. Hydraulic dredges, best adapted to sand, handle loam and clay also.

The muck ditch and retaining longitudinal dikes are built by dry land methods and the fill between the retaining dikes placed by the dredge. Ponding is prohibited to avoid segregation of finer material.

For all types of primary equipment now used, auxiliary equipment, such as bulldozers and scrapers, is needed to dress the levee to the final gross section.

The most desirable method of placing the material, namely, in full width, even, horizontal layers is only partially attainable by most types of levee building equipment. The shrinkage allowances vary with the method of construction and are generally as follows—

for hydraulic placement	8 per cent
for layer construction	15 per cent
for construction by tower machines and drag lines	25 per cent

After all material has been placed the levee surfaces are dressed smooth and planted with small living sods of Bermuda or other suitable grass; these sods are placed not more than 18 inches apart and quickly spread into a continuous growth.

Maintenance

The ordinary maintenance of levees comprises repairs of any deteriorated spots on crown or slopes, filling depressions, holes and cracks, removal of brush and weeds, preservation of a good sod condition, periodical mowing, upkeep of wave fences and slope protection, if any, and policing during high water periods.

Levee Failures

The major causes of levee failures are—

Overtopping.
Undermining following loss of bank and foreshore.
Seepage and saturation.

A well sodded levee built of material resistant to erosion such as seasoned buckshot, will resist for some time a limited depth and velocity of flow over the crown. It can be saved, however, only by an early fall in the flood stage or by protective measures. A levee of loam or sand fails promptly after being overtopped. Where adequate crown width exists and men and materials are available for topping out the grade as the flood rises, levees can be and frequently are held against flood heights about 5 feet above the crown.

Loss of bank sometimes reaches several hundred feet during a season and may occur during all stages. When the receding bank reaches the toe of levee, the latter is of no further value.

Seepage failures are caused by seepage either through the levee proper or through the foundations. A considerable amount of either may occur without serious danger to the levee, particularly so long as the seepage water remains clear. When the seepage water turns muddy, trouble is imminent. Failure from levee seepage, when it occurs, is usually the sliding on an inclined plane of a large section from near the crown.

Percolation of water through the levee is facilitated by cracks and openings due to shrinkage and to burrowing animals, which can be eliminated by maintenance; also to voids left by decay of vegetable matter, if any.

The use of sections sufficiently massive to contain with certainty the seepage line from extreme and long continued floods is deemed economically impracticable and unnecessary. A saturated condition develops slowly and the levee may be held by emergency treatment of the slopes with provision to carry drainage away from the landward slope of the levee and the area immediately behind it.

The superiority of a coordinated system of levee design and construction over a system of execution from the viewpoint of local protection may be seen from the generally progressive decrease in number of crevasses in the Mississippi levees below Cairo, Illinois, during the years of major floods since 1882, when the Mississippi River Commission began to function actively. The number of crevasses decreased from 284 in 1882 and 224 in 1883 to 13, of which 2 were artificially created, in 1927.

The crevasse which occurred at Mound Landing, Miss., in 1927 was 3047 feet wide, 60 feet or more deep and had an estimated discharge of 450,000 second-feet.

Interior Drainage

To the extent that the levee line is continuous, it cuts off drainage into the stream leveed. Openings are necessarily left for the discharge of large tributaries and the levee lines may be carried up the banks of these tributaries for considerable distances. Smaller streams may be passed through the levee in pipe culverts with automatic valves, or in sluiceways with sliding or folding gates. When high water rises above the levee outlet, the same situation is presented that arises if the drainage is entirely cut off—the necessity for pumping, storage or diversion.

There are practically no openings through the Mississippi levees as they are deemed to present too great a percolation hazard in view of the levee material commonly used. Interior drainage from small areas is allowed to accumulate in natural depressions and drainage from the larger areas is diverted so as to find its way into the backwater storage areas of the larger tributaries. As an example, when the Cypress Creek gap in the west bank levee was closed in 1921, the drainage had been diverted so as to pass through channels partly artificial and partly natural, into the Red River Basin about 160 miles below the former mouth of the Creek.

Expenditures

The expenditures upon levees under the jurisdiction of the Mississippi River Commission from 1882 to date are approximately as follows—

From 1882 to 1926 inclusive—

from funds of the United States	$ 71,090,000
" " " states and local organizations	167,011,000
	$238,101,000
Appropriated by the Flood Control Act of 1928 for levees, exclusive of floodway levees, $139,600,000; expended, 90 per cent or more	$125,000,000
Total, about	$363,000,000

References

The classic reports of Ellet (1851) and of Humphreys and Abbot (1861) are now chiefly of technical and historical value. More recent authoritative works on the subjects are—

"The Improvement of Rivers", 2 vol.—Thomas and Watt, 1913.
"The Regulation of Rivers"—J. L. Van Ornum, 1914.
"The Improvement of the Lower Mississippi River for Flood Control and Navigation", 3 vol.—Major D. O. Elliott, 1932.

Previous Reports by Committee

Previous reports of this Committee upon the subject of levees may be found in—

Proceedings, Vol.	30	page	271;	Bulletin	311, Nov. 1928.
" "	31	"	1341;	"	324, Feb. 1930.
" "	33	"	215;	"	341, Nov. 1931.

Conclusion

Conditions governing the selection of a suitable type of levee construction vary so widely at various locations that no brief general rules may be laid down other than the necessity of weighing such of the various controlling factors, attempted to be mentioned in this report, as may bear upon the individual case. In connection with any proposed project a review of experience upon similar projects will be beneficial.

Recommendation

Receive as information; continue subject for a final report upon suitable types of dikes and mattresses.

Appendix D

(7) ECONOMIC PRINCIPLES INVOLVED IN CLEARANCES OVER INLAND NAVIGABLE WATERWAYS

D. J. Brumley, Chairman, Sub-Committee; W. D. Faucette, R. A. Feldes, I. W. Geer, C. S. Kirkpatrick, P. G. Lang, Jr., F. E. Morrow, G. P. Palmer, B. H. Prater, G. R. Smiley, Edwin F. Wendt, J. E. Willoughby.

Last year the Committee reported on "Definitions of Terms Pertaining to Public Improvement Projects", which was approved by the Association at its annual meeting as recommended practice for publication in the Manual.

That report was developed during the study made by railway representatives on waterway projects, such as the Calumet Waterway in the Chicago metropolitan area, the waterways connecting Lake Erie with the Ohio river system, and other similar waterway projects in the United States. The development of these studies has suggested the desirability of enumerating some of the details not fully set forth in the report last year.

As a rule, the Congressional House Committee on Rivers and Harbors originates waterway projects for both navigation and flood control. This committee refers them to the War Department for survey, investigation, analysis, and report. In turn, the War Department issues instructions to the Division Engineers to carry out the surveys and investigations and they delegate the work to the District Engineer in whose district the proposed project is located. The first step in the office of the District Engineer is to hold a public hearing, at which time the proponents and opponents of the waterway development are given an opportunity to express their views. After the public hearing, the District Engineer makes a survey and estimates the construction costs, determines the available commercial freight tonnage, computes the transportation costs, and likewise develops the savings, if any, to the public. The District Engineer passes the report with his recommendation to a Division Engineer or to a special board of engineers (all U.S. Engineers) who forward it with recommendations to the Rivers and Harbors Board (also U.S. Engineers). Upon the completion of the deliberations of the Board, the report with recommendations is forwarded to the Chief of Engineers, U.S.A., and his report with further recommendations is sent to the Rivers and Harbors Committee of the House of Representatives of Congress. If approved by the House, it is then sent to the Committee on Commerce of the Senate. Upon the completion of approval by the Senate and House, the project is then ready for the approval and signature of the President.

Usually, public hearings are held by the District Engineer, at which all interested parties are given an opportunity to be heard. Either party, on request, is given the right to file plans, estimates, and other pertinent data in the form of a brief, within a specified time prescribed at the hearing. Unless the proposed waterway project is of far-reaching importance, public hearings are not held by the Rivers and Harbors Board. In general, the public hearings before the District Engineer present the best opportunity to secure modifications in plans or the inclusion of data not disclosed by the District Engineer's investigation. When the report is concluded by the District Engineer, it becomes a semi-confidential document and is not available for detailed inspection. The importance of the railway companies presenting data to the District Engineer cannot be over-stressed as this presents the best opportunity of getting the company's data into the records that are finally lodged with Congress.

These waterway projects are designed to enlarge and expedite coastwise and lake traffic, to open waterways to be operated in competition with rail traffic, or for the purpose of hydro-electric developments, flood control, or irrigation. The railways built many years ago met the conditions existing then by spanning the navigable waterways and fixing the grade elevation of the roadbed to be safe above maximum high water.

Disregarding the loss in rail traffic occasioned by the new or improved waterways, the effect on the physical railway plant may be far-reaching. Such improvements carry with them demands for greater vertical clearances, with longer spans, or cause the inundation of railway property in flood control areas. It is only fair to the District Engineer that he should be advised of all the facts as his survey and investigation proceed. The railway engineer should present him with the relevant facts at *that* time, or should arrange to file an exhaustive brief after the public hearing is held and before the District Engineer has completed his final report. The record thus made, either in support of the proposed improvement or against it, will accompany the District Engineer's report through the various channels to the Rivers and Harbors Committee of the House of Representatives.

Many waterway projects are now in process of construction and more are passing through the established routine of survey and recommendation for authorization.

The Army Engineers are unlike those engaged by industry. The Army Engineer takes into his consideration only those items of cost which are directly concerned with the creation of the project and which are to be borne by the government from funds secured through taxation. He usually does not include the items of cost which may be imposed upon individuals, municipalities, or railway companies for collateral costs incurred in building longer and higher bridges and the relocation of facilities serving industries and probably the relocation and reconstruction of the railway companies' yards and other facilities. The District Engineer's cost of operation does not include interest on the increased capitalization due to collateral costs, or to increased operating expense due to changed conditions. His estimates do not include amortization, obsolescence, and interest on capital invested in the project. The engineer in industry must prove his case and show that the gross income is large enough to meet the recurring annual expense of operation, maintenance, amortization, taxes, insurance, and interest on invested capital, and have enough left over to attract the investment of private capital.

It is to be observed that Army Engineers include in their estimates of savings those which accrue directly to the businesses using the improvement and do not undertake to develop the loss in business that may be sustained by the competitors to the waterways. The capital for the waterway improvement is provided by levies on all business of corporations, and individuals as well, and the interest on the money so invested is not passed on to the waterway users. The money spent on waterway projects where navigation is involved ordinarily means loss of traffic to competing forms of transportation. The railways, as substantial taxpayers, should present complete data, where possible, of such loss.

Waterways or other classes of industrial projects financed by government money, levied by taxation, should be put on the same basis as like improvements financed by private capital.

The initial cost should include the construction cost entailed in carrying out the project, the cost to be incurred by municipalities, corporations and individuals to meet the changed conditions imposed by the construction of the Federal improvement project, and the government should also assume the extra cost of maintenance and operation created by the changed conditions.

Representatives of the railways should include in their brief to be presented at all public hearings on waterways the elements of initial cost, development cost, and annual cost, developed in the "Definitions of terms Pertaining to Public Improvement Projects", and contained in this committee's report which was presented to the Association in March, 1935.

It is fitting and proper that every waterway project should be considered in the light of these cost items. Industry, to succeed, must meet all of these requirements and it is of utmost importance that these facts be brought to the attention of the District Engineer at the public hearing. To make the proper showing, final cost estimates must be made on carefully prepared plans and on data accurately supported. The tonnage of traffic must be compiled by experts with supporting data on the business that would come to the new transportation line. All of the data to be presented should be assembled in logical order and the text so framed as to make it a self-contained document.

The real purpose of the plans, estimates, and supporting data, prepared by both the District Engineer and the railway engineer, is to determine the fundamental question of economic justification. It is assumed that the responsibility of the engineer then ceases.

It is recommended that this report be received as information and the assignment for next year be extended to include examples of the application of these principles to waterway projects that have been in operation for several years.

CLEARANCES FOR STRUCTURES OVER NAVIGABLE WATERS

In the development of navigable waterways, many projects involve the widening, deepening, or straightening of existing waterways, or the creation of new ones. The improvement by widening and deepening existing channels usually implies that their future operation will be with craft of greater draft, beam and height.

Land transportation interests, including the railways, are often required to meet demands for greater horizontal and vertical clearances than are needed.

At the annual meeting of this Association in 1934, a progress report was submitted, including a resolution embodying a fundamental principle involved in the establishment of clearances for structures over navigable waters, as follows:

> "That proper clearances for navigable streams are those which will not unduly interfere with the operation of either land or water transportation, cause unwise expenditures to be made for physical readjustments, or place burdensome restrictions on their future expansion. There must be an economic balance in the interest of both forms of transportation."

The question of the economic balance between land and water transportation involved in waterway projects has been studied by other engineering societies, namely: The American Society of Civil Engineers and the Western Society of Engineers, whose conclusions are alike in fundamental essentials.

Since the prospects are that the development of navigable waterways will continue, the Committee recommends that the following be adopted and published in the Manual:

Resolution

> "Proper clearances for structures over navigable waters are those that will not interfere with the operation of either land or water transportation, cause unwise expenditures to be made for physical readjustments, or place burdensome restrictions on their future expansion. There must be an economic balance in the interest of both forms of transportation."

Appendix E

(8) COST TO RAILWAYS FOR CONSTRUCTION, MAINTENANCE AND OPERATION OF BRIDGES OVER NAVIGABLE WATERWAYS

F. E. Morrow, Chairman, Sub-Committee; D. J. Brumley, W. D. Faucette, R. A. Feldes, I. W. Geer, C. S. Kirkpatrick, R. J. Middleton, B. H. Prater, A. N. Reece, Edwin F. Wendt, J. E. Willoughby, S. L. Wonson.

Last year the Committee presented a form to be used by the Railroad Companies in compiling data on the cost of construction, maintenance and operation of bridges over navigable waterways. This form was presented as information only inasmuch as it was felt desirable to give the matter further consideration.

The Committee has changed the proposed form to a questionnaire entitled "Railroad Structures Over Navigable Streams or Waterways in the United States". The Committee has had the benefit of suggestions made by Dr. C. S. Duncan, Economist, Association of American Railroads, in the preparation.

It has been the purpose of the Committee to prepare a questionnaire which would develop the information needed to ascertain the costs which are borne by the railroads on account of the navigation requirements on streams and waterways. It is believed that the attached questionnaire will develop that information in a uniform manner and it is recommended for approval.

QUESTIONNAIRE

RAILROAD STRUCTURES OVER NAVIGABLE STREAMS OR WATERWAYS IN THE UNITED STATES

Description

(1) Location—Railroad Station and State
(2) Name of Stream or Waterway
(3) Distance in miles from established head of navigation
    (a) Upstream
    (b) Downstream
(4) Ruling dimensions of stream for navigation purposes
    (a) Width
    (b) Depth
(5) Present annual tonnage moving on Waterway at point of crossing:
    (A) Commercial
        (a) No. of Freight Boats
        (b) Cargo Tonnage
    (B) Waterway construction and maintenance tonnage
        (a) No. of boats
        (b) Cargo tonnage
    (C) No. of passenger boats
(6) Date of original crossing by railroad
(7) Date of construction of present bridge
(8) Horizontal clearance—at right angles to stream—present bridge
(9) Vertical clearance—low point of bridge to established high water—present bridge
(10) Movable or fixed bridge—present bridge

Construction Cost and Obsolescence

(11) Construction cost of present bridge in excess of cost of bridge of same loading if stream or waterway was non-navigable.
(12) Annual interest at 5% on cost shown in (11)
(13) Annual obsolescence charge at 2% on cost shown in (11)
(14) Annual taxes on cost shown in (11)
(15) Total: (12) plus (13) plus (14)

Operation—Annual

(16) Bridge operating labor—amount
(17) Fuel, power and supplies for operation
(18) Excess cost, due to increased gradients, train stops and speed restrictions
(19) Total: (16) plus (17) plus (18)

Annual Excess Maintenance Cost of Improvements Covered in (11)

(20) Structures, tracks, machinery, signals, interlocking, fenders, etc.
(21) Total annual excess charges: (15) plus (19) plus (20)

Details of Use of Movable Bridge

(22) Total annual openings for waterway construction, maintenance or inspection boats
(23) Total annual openings for commercial boats including private boats
(24) Total openings per annum

REPORT OF COMMITTEE XXII—ECONOMICS OF RAILWAY LABOR

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J. R. Watt,
C. R. Wright,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual. Progress in study—no report.

(2) Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work (Appendix A). Progress report.

(3) Economics of methods of weed killing (Appendix B). Progress report.

(4) Gang organization and methods of performing the more common tasks of maintenance of way work (Appendix C). Progress report.

(5) Out-of-face renewal of track in view of the increasing life of basic units of track construction (Appendix D). Progress report.

(6) Economies in labor to be effected through increased capital expenditures. Progress in study—no report.

(7) Economies in track labor to be effected in the maintenance of joints by welding and the use of reformed bars (Appendix E). Progress report.

(8) Effects of recent developments in maintenance of way practices on gang organization (such as use of heavier rail, treated ties and labor-saving devices which make practicable small section forces, and conducting the major part of maintenance work with extra gangs) (Appendix F). Progress report.

(9) Comparative costs of maintaining track on various kinds and depths of ballast (Appendix G). Progress report.

The Committee on Economics of Railway Labor,
F. S. Schwinn, *Chairman.*

Bulletin 382, December, 1935.

Appendix A

(2) ANALYSIS OF OPERATIONS OF RAILWAYS THAT HAVE MADE MARKED PROGRESS IN REDUCTION OF LABOR REQUIRED IN MAINTENANCE OF WAY WORK

J. A. Parant, Chairman, Sub-Committee; W. R. Bennett, H. A. Cassil, J. I. Catherman, W. O. Frame, A. C. Harvey, Elmer T. Howson, C. T. Jackson, C. R. Knowles, J. B. Martin, G. M. O'Rourke, J. B. Trenholm, W. H. Vance.

In carrying out its assignment your Committee has selected the Norfolk & Western Railway as the next property to study.

In November several members of both the Sub-Committee and General Committee made an inspection trip over this railroad and obtained valuable information for a subsequent report.

Your Committee reports progress and recommends the subject be continued.

Appendix B

(3) ECONOMICS OF METHODS OF WEED KILLING

C. R. Knowles, Chairman, Sub-Committee; C. W. Baldridge, J. I. Catherman, W. S. Hanley, C. A. Johnston, P. T. Robinson, F. H. Rothe, H. M. Stout, J. B. Trenholm, W. H. Vance, J. R. Watt, C. R. Wright.

In discussing the economics of methods of killing weeds it is extremely difficult to evaluate the benefits because of the many factors involved, such as the density of the weeds, the rate and persistence of growth, the traffic density and the relative importance of the railroad. However, it is generally agreed that a roadbed free from weeds is to be desired. Each year sees improved methods of killing weeds, and under normal conditions weed control is being given increased attention by the railroads.

It is recognized that proper weed control includes not only the roadbed but the entire right-of-way from fence to fence, including station grounds, shops and yards. However, in this report the Committee has confined its discussion to that portion of the roadbed within the limits of the shoulders and especially the ballast section.

The term "noxious weeds" is often used in connection with the question of weed control. From the standpoint of this report any form of vegetation within the limits of the roadbed is considered objectionable and methods for its control desirable. For example, a rosebush or the growth in the ballast of wheat leaking from a grain car is an objectionable weed from the standpoint of our discussion of the subject.

The control of weeds on the railroad right-of-way has constituted a problem since the first railroad was built. For many years the methods followed might be considered rather primitive. It is only within the last quarter of a century that other than hand methods have been employed and that the removal of weeds has become more widely recognized as a fundamental of good maintenance rather than as a fad or a luxury. As improved methods of removing weeds have been developed the practice of weeding has been extended.

Many methods of weed control have been developed during the last quarter of a century, including steam weed destroyers, flame weed burners, track-operated and tractor-driven mowing machines, ballast discers, chemicals and oil. Opinions differ as to the relative merits of different methods of weed control. It is evident, however, that there is a wide field for each type of equipment so far developed, either where used alone or in combination.

It is the purpose of this Committee to discuss the necessity for weed control, types of troublesome weeds, the most effective killing stage, the reasons for their removal, the methods followed and the cost of weed removal. However, it should be understood that such figures on the cost of weed control as are submitted are given for what they may be worth, since cost figures of one railroad may be of little value to another.

WHY KILL WEEDS

The presence of vegetation in the roadbed prevents proper drainage, one of the essentials of good track. Continual growth catches and holds dust and dirt and, with subsequent decay, fills the ballast with foul material, with the result that it becomes dirty and clogged, until it sometimes becomes necessary to clean or remove the old ballast and substitute new. Therefore, keeping a roadbed free from weeds not only reduces maintenance costs but additional capital expenditures as well.

The benefits derived from the destruction of weeds in the roadbed may be summarized briefly as follows:

(a) Improves drainage of track
(b) Facilitates the drying out of track
(c) Reduces the fouling of the ballast
(d) Retards the decay of ties
(e) Facilitates tie and track inspection
(f) Reduces interference with locomotive traction
(g) Improves the appearance of the roadbed
(h) Stimulates employee morale
(i) Reduces fire hazards
(j) Reduces labor requirements for normal track maintenance

Railway Engineering and Maintenance for June, 1933, published a tabulation of the principal reasons for weed destruction, as reported by 34 roads, as follows:

Objectives	*Order of Importance**						
	1	2	3	4	5	6	7
To improve appearance	6	6	5	3	6	6	1
To prevent fouling of ballast	14	8	3	4	5		
To facilitate drainage	5	15	9	1	3		1
To retard decay of ties		4	15	6	5	2	2
To facilitate tie and track inspection		2	2	8	8	11	1
To reduce interference with locomotive traction	10	2	3	3	5	7	3
To stimulate employee morale			1	5		3	17

In commenting upon the above summary seven primary reasons were given as objectives in practicing weed eradication. Two of the roads reporting made separate tabulations for branch lines, in which they changed the relative order of importance as compared with main lines. Several others included further reasons, some of which they ranked as of first or second importance, such as to reduce fire hazards to stored cars, to eliminate or reduce snow trouble in winter, to facilitate the renewal of ties, to reduce labor cost of trackwork, to assist in detecting slight irregularities in line and surface, to improve safety and to conform to state laws. The article goes on to state further:

"The majority of the roads were of the opinion that the most important reasons for removing weeds from tracks are to prevent fouling of the ballast and to facilitate drainage. Retardation of decay in ties, improved appearance and reduced interference with traction follow in the order given. Ten roads, however, gave interference with traction as the most important reason. A few gave the facilitating of track inspection as an important reason, while more than half of the roads assigned least importance to the stimulation of employee morale. Six roads considered improved appearance to be of first importance; six placed this reason second and five assigned it to third place.

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* Figures show number of roads rating each reason, in the order of importance.

"Twelve roads asserted that neither the volume nor the character of traffic nor the standard of track construction is taken into consideration, and three others said that they attach little importance to these matters. Eight stated that the volume of traffic is given first consideration in planning the annual program of weed elimination, while on two roads the volume and character of the passenger traffic exert the largest influence.

"Five roads gave the standards of track construction and one road the standards of maintenance as the principal factors in determining the amount and character of the weed elimination work that is to be done. In addition, three roads stated that the total volume, the amount and character of passenger traffic and the standards of track construction are all given weight in distributing the appropriations for this work. Several roads make a point of keeping their rock-ballasted track free of weeds and then do as much on the remaining lines of the system as appropriations will permit. In commenting on the standards of track construction as a basis for preparing the annual weed-destroying program, attention was called to the fact that these standards are generally determined by the volume and character of the traffic that is handled, so that indirectly the matter is again based on traffic."

WHAT WEEDS TO KILL

A Manual of Weeds, by G. A. Eljiva, lists 2,263 troublesome plants in the United States and Canada, 64 of which are poisonous or otherwise harmful to animal life. The United States Department of Agriculture gives a list of the 50 worst weeds in the United States, together with brief descriptions of their flowers for identification, and the regions in which they are most troublesome. Included in this tabulation are most of the weeds found in the roadbeds of railroads, but not all of them; a notable omission is sweet clover, a plant that is particularly troublesome throughout the mid-western and eastern states. This list follows:

(A–annual, B–biennial, P–perennial)

Common name and duration of life	*Color, size and arrangement of flowers*	*Section where most injurious*
Barley, foxtail barley, P	Green; spike with long bristly glumes	Minnesota to Texas and California
Bermuda grass, P	Purple; 1/12-in. spikes	Maryland to Missouri and southward
Bindweed, field bindweed, P	White or pink; 1-in., solitary	Entire United States, especially California
Bindweed, hedge bindweed, P	White or rose; 2-in., solitary	Mississippi Valley region
Bitterweed, A	Yellow; ¾-in., head	Virginia to Kansas and southward
Bracken, brake, P	No flowers—	Northwestern States and the Pacific Coast
Broom sedge, P	Green; ¼-in., racemes	Massachusetts to Michigan, Florida and Texas
Buffalo bur, A	Yellow; ½-in., solitary	Illinois and Colorado to Texas
Bur-sage, wooly bur-sage, P	Yellowish; heads; ⅛-in.	Montana to Mexico
Carrot, wild carrot, B	White; very small; umbels	Maine and Virginia to the Mississippi
Chess, cheat, A	Green; spikelets in panicles	All grain sections

Common name and duration of life	*Color, size and arrangement of flowers*	*Section where most injurious*
Chickweed, common chickweed, A	White; ⅛-in., cymes	Entire United States
Cocklebur, A	Green; ¼-in., head	Entire United States
Crabgrass, A	Green; spikes	Entire United States, especially the South
Daisy, oxeye daisy, P	White with yellow center; 1-in., heads	Maine to Virginia and Kentucky
Dandelion, P	Yellow; 1¼-in., head	Entire United States
Dock, curly dock, P	Green; ¼-in., panicle	Entire United States
Dodder, alfalfa dodder, field dodder, A	Yellow; ⅛-in., clusters	All clover and alfalfa regions
Dodbane, Indian hemp, P	Greenish white; ¼-in., terminal clusters	Upper Mississippi Valley
Foxtail, yellow foxtail, pigeon grass, A	Green; spikes	Upper Mississippi Valley
Garlic, wild garlic, P	Flowers rare; umbels with bulblets	Rhode Island to Georgia and west to Missouri
Hawkweed, orange hawkweed, devil's paintbrush, P	Orange; 1-in., heads	Maine to Ohio
Horse nettle, P	Purple; 1-in., solitary	Entire United States
Ironweed, P	Purple; 1/3-in., heads	Maine to Maryland and Iowa to Kansas
Jimson weed, A	Purple; 3-in., solitary	Maine to Minnesota and Texas
Johnson grass, P	Green; ⅛-in., panicle	Virginia to Texas and California
Lamb's-quarters, A	Green; very small; panicle	Entire United States
Lettuce, prickly lettuce, A	Yellow; ¼-in., heads in panicles	Ohio to Iowa, Utah to California
Morning-glory, A	White, purple, or blue; 1½-in., solitary	New York to Missouri
Mustard, wild mustard, charlock, A	Yellow, ½-in., racemes	Maine to Washington
Nut grass, coco, P	Brown; 1/16-in., spikelets	Maryland to Florida and Texas
Pennycress, French weed, A	White; ⅛-in., racemes	North Dakota and Minnesota
Peppergrass, perennial peppergrass, P	Whitish; ⅛-in., corymbs	Rocky Mountain region chiefly
Pigweed, redroot, careless weed, A	Green, very small; spikes in panicles	Entire United States
Plantain, buckhorn, P	White; 1/16-in., spike	Entire United States
Poison ivy, P	Greenish white; ⅛-in., panicles	Entire United States
Puncturevine, A	Pale yellow; ½-in., solitary	Kansas to California
Purslane, pusley, A	Yellow; ¼-in., solitary	Entire United States
Quack grass, P	Green; spike	Maine to Pennsylvania and Minnesota
Ragweed, common ragweed, A	Yellow; ¼-in., small heads on spikes	Entire United States
Russian thistle, A	Purplish; ¼-in., solitary	Minnesota to Washington and southward
St. Johnswort, P	Yellow; ¾-in., cymes	Maine to North Carolina and Iowa
Sand bur, A	Green; 1/3-in., bur	Maine to Florida and westward to Colorado
Smartweed, A	Light rose; 1/16-in., racemes	Maine to Minnesota, Florida, and Texas
Sorrel, sheep sorrel, P	Red; ⅛-in., panicles	Entire United States

Common name and duration of life	*Color, size and arrangement of flowers*	*Section where most injurious*
Sow thistle, pernenial sow thistle, P	Yellow; ¾-in., heads	Maine to Minnesota
Thistle, Canada thistle, P	Purple; ¾-in., heads	Maine to Pennsylvania and Washington
Thistle, common thistle, bull thistle, B	Reddish purple; 1-in., heads	Maine to Virginia and Washington
Wild oats, A	Green; panicles; similar to oats	Wisconsin to Washington
Wintercress, yellow rocket, P	Yellow; ¼-in., racemes	Maine to Virginia and westward

DEFINITIONS OF TERMS USED IN DESCRIBING FLOWERS OF WEEDS

Cyme.—a flat-topped flower-cluster.

Glume.—a chaff-like scale of the inflorescence of grasses.

Panicle.—a loose compound flower-cluster, produced by irregular branching.

Raceme.—a flower-cluster arranged at intervals on a stem.

Umbel.—a flower-cluster in which a number of pedicels radiate like the stays of an umbrella.

WHEN TO KILL WEEDS

The determination of the stage in the growth of weeds at which methods of destruction are most effective necessitates a knowledge of their habits and methods of reproduction. It is generally assumed that the most effective time for controlling weeds is in the early part of the seeding stage. While this is true of annuals it does not apply to biennials and perennials. Also, it must be remembered that seeds of certain weeds have a remarkable vitality in the soil.

Weeds may be divided into four main groups—annuals, winter annuals, biennials and perennials.

Annuals complete their growth in one year; that is, the seeds germinate in the spring or summer and the plants die in the fall. Most of the annuals produce large quantities of seeds which in certain species retain their vitality in the soil for many years. The seed of the Canada thistle has a known life of 20 years or more while the seeds of black mustard, purslane and evening primrose have a life of 50 years or more. Seeds of other weeds, such as quack grass and horse nettle have a life of from 4 to 10 years. Therefore, the most effective time to destroy weeds is while the seeds are germinating.

Winter annuals include a small group of weeds which behave like fall wheat although some of them may act as true annuals. The seeds usually germinate in the fall under favorable conditions and the plants complete their growth the following spring. Therefore, discing in the spring is most effective in destroying this class of weed.

Biennials complete their growth in two seasons, behaving in a manner similar to red clover and sweet clover. The seed is produced the second season after which the plants die. Weeds of this class may be killed in the first year of their growth by cutting them off below the surface of the soil.

Perennials are plants that produce roots, rooting stems or root stalks that remain alive for several years. The primary function of the root stalks, as for example the Canada thistle, is food storage for vegetable reproduction. It has been found that the food reserves of roots in undisturbed areas are usually lowest during the blossoming periods and highest during the early winter and early spring. This means that the top growth, after ripening, supplies food to the root system. Therefore, the most effective stage in the destruction of these weeds is that which will prevent the top growth from early summer until the end of the growing season.

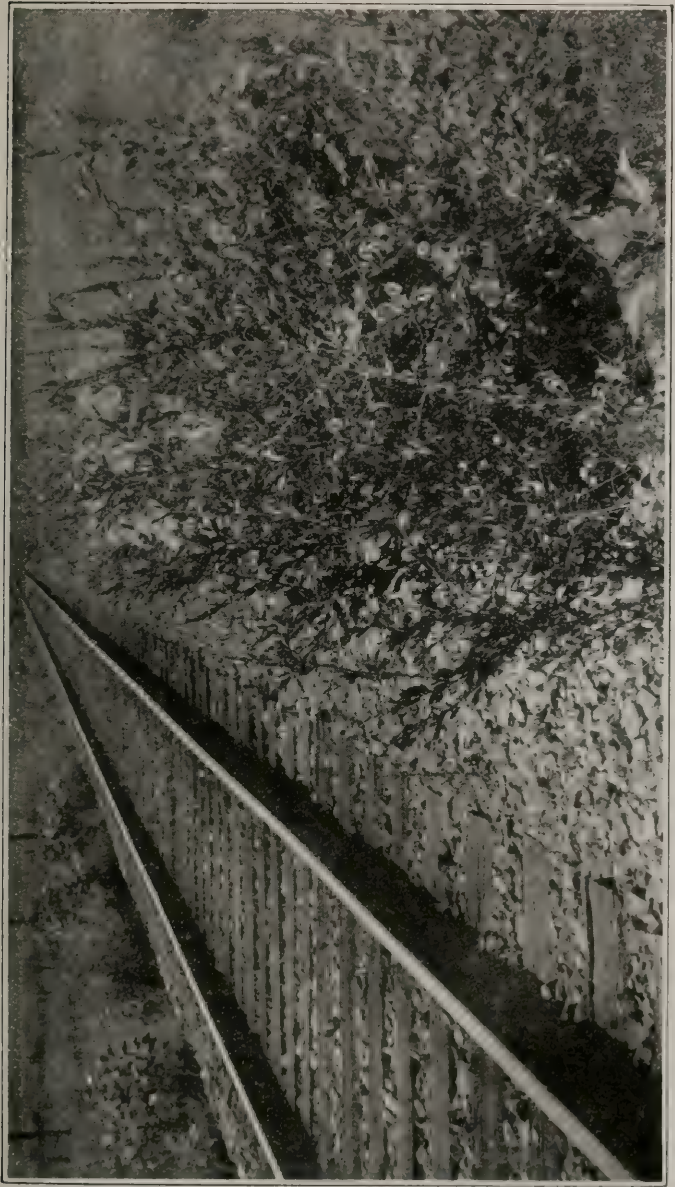

FIG. 1.—Track Immediately Prior to Initial Treatment. Vegetation Consists of Sunflowers, Russian Thistle, Wild Lettuce, Wire Grass and Blueweed.

HOW TO KILL WEEDS

The methods followed in killing weeds in the roadbed include, hand weeding, flame burners, steam weed destroyers, mowing machines, ballast discers and the application of chemicals and oil. The cost of removing the vegetation from the roadbed depends upon the method used, the rate of growth and the density and persistence of the growth. The kind of ballast used, of course, influences the growth; it also influences the cost of keeping the ballast section clean by the destruction of weeds.

The various methods of killing weeds are coordinated to a certain extent, particularly track mowers and burners. Where track mowers and weed burners are used in the same territory, the mower is operated first and followed with a burner, after allowing a sufficient interval for the weeds to dry so that they will burn readily and be completely consumed when the burner passes over them. If the track is to be treated with chemicals or oil, any discing or other disturbance of the ballast should precede their application.

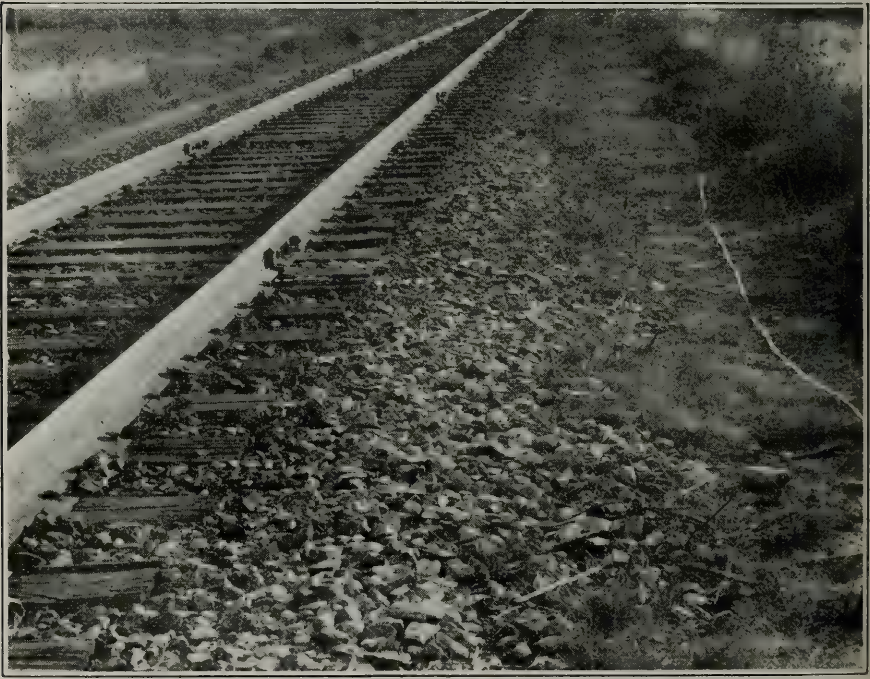

FIG. 2.—Same track as shown in Fig. 1 following initial treatment of 160 gals. of chemical per mile. All vegetation in the treated area killed except wire grass which appears to be about 50 per cent killed.

The standard of maintenance and the volume and character of traffic vary between roads and on different parts of the same railroad. Because of these varying requirements, methods followed in weed control differ widely, and, as with the benefits derived, the methods of weed control are affected by the rate of growth, and by the density and persistence of vegetation, which vary in different sections of the country and even on different districts of individual roads.

Prior to about twenty-five years ago, hand methods were depended upon entirely for the control of weeds. They were pulled from the ballast by hand and removed from the balance of the roadbed with shovels and scuffle hoes. Even with the comparatively low wages prevailing at that time, hand weeding was not only expensive but had the added disadvantage that it was necessary at times when the labor was needed for other maintenance of way work. The introduction of weed burners, chemicals, mowing machines and discers has effected marked economies in the removal of weeds. These devices have also permitted more extensive weeding than was followed by the hand methods for when hand methods alone were employed weed removal was confined largely to the more important main line tracks.

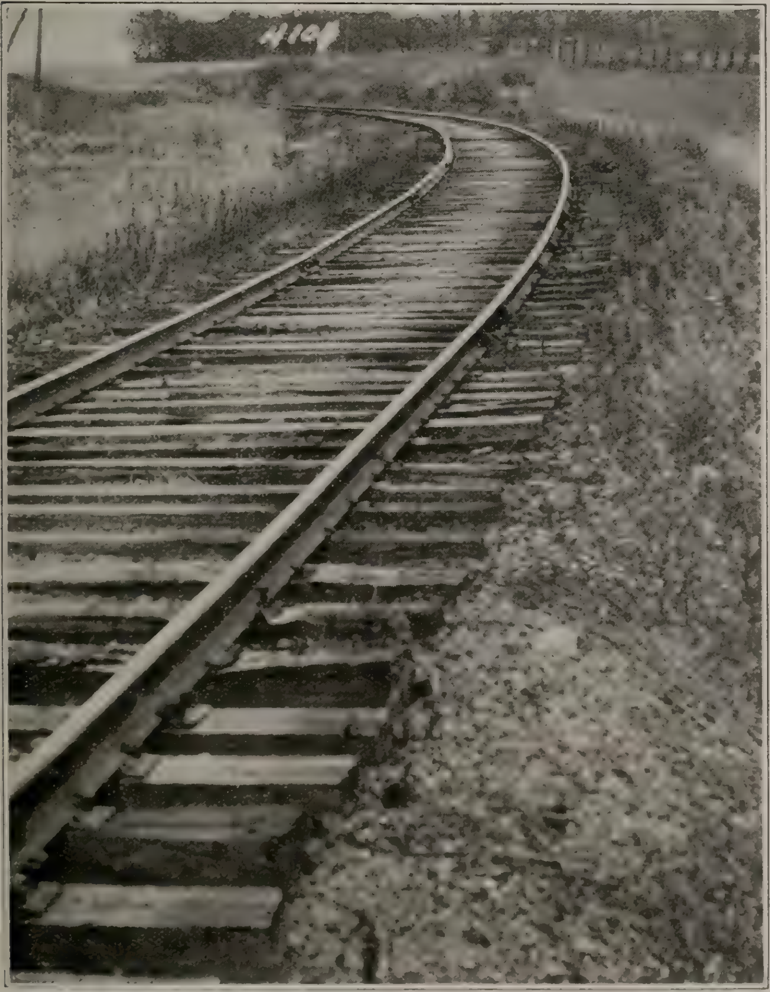

FIG. 3.—Gravel Ballasted Track Prior to Discing.

Hand Weeding

While hand weeding is the most expensive method of removing weeds from track it will probably never be entirely supplanted by other methods. With present day labor costs, however, extensive track weeding by hand cannot be justified bceause of its excessive cost, together with the cost of replacing the material removed from banks by scuffle hoes and shovels. This method will, therefore, be confined to conditions where the use of more economical methods are impractical.

Steam Weed Destroyers

The steam weed destroyer consists of a system of piping arranged on a flat or other car in such a manner to permit of the application of superheated steam direct to the vegetation to be destroyed at temperatures of from 600 to 650 deg. This type of weed destroyer does not actually destroy the weeds and will not kill the hardy or fibrous vegetation but merely wilts the tops and keeps them down temporarily. The less hardy types are killed for the season. The number of trips necessary depends upon the character of the vegetation and the extent to which it is desired to keep it down. Best results are obtained by making the initial application during the early growing season while the vegetation is tender, followed by a second steaming three or four weeks later.

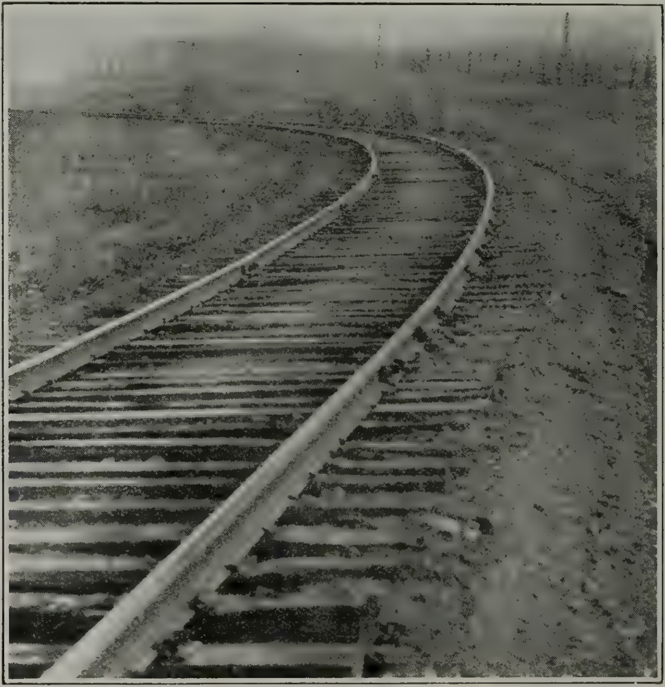

FIG. 4.—Same Track as Shown in Fig. 3 After Discing.

Weed Burner

This machine consists essentially of a specially-designed steel frame mounted on single axle trucks and is self-propelled. The oil tanks and the engine used for propelling the car and operating the pumps, blowers, etc., are mounted on this frame. In some cases two engines are used, one for propelling the machine and the other for operating pumps, blowers, etc.

This burner is built in two general types, the oven type and the extended burner type. The track oven used in the oven type burner is approximately 8 ft. long by 9 ft. wide and confines the heat and flame within the area of the oven. The extended burner type is equipped with from two to ten burners on extended arms which may be operated individually or collectively and controlled at the will of the operator. The principal objection to burning weeds is the fire hazard, particularly in timbered or grain raising countries and in dry periods of the year when the fire hazard is serious. The use of the flame burner necessitates extremely careful handling and a patrol to follow it closely to extinguish incipient fires.

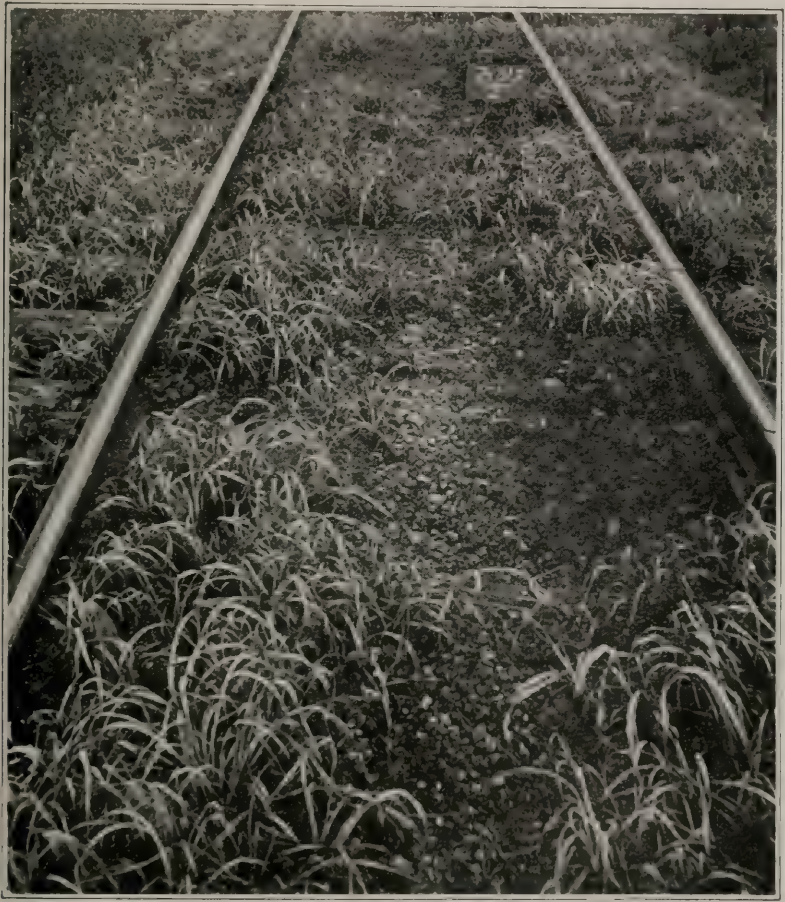

Fig. 5.—Before Burning.

Mowing Machines

The use of track-operated mowing machines is confined almost exclusively to the control of weeds in the roadbed. They are equipped with standard sickle bars of varying lengths. Most track mowers are provided with engines for operating the sickles and are towed by a motor car. Horsedrawn mowers, hand operated mowers and sickles mounted upon tractors are also used to a limited extent for the removal of weeds in the roadbed.

Ballast Discers

Ballast discers consist of heavy discs mounted on arms extending from one or both sides of a car, with facilities for raising or lowering the discs as required. The discer car may be self-propelled, or, with the lighter types, towed by a motor car. The heavier discers are also equipped with scarifiers for loosening up cemented ballast.

Ballast discers are effective in keeping the ballast shoulders clean and removing weed growth. In addition they clean and shape the ballast shoulders and improve drainage throughout the shoulders through stirring up the ballast and removing foul material and dirt.

Chemicals

Chemicals are efficient in the control of weeds when applied in sufficient quantities and with sufficient frequency. It is claimed by some that the continued application of chemicals has a tendency to sterilize the soil. Others are of the opinion that the reduced

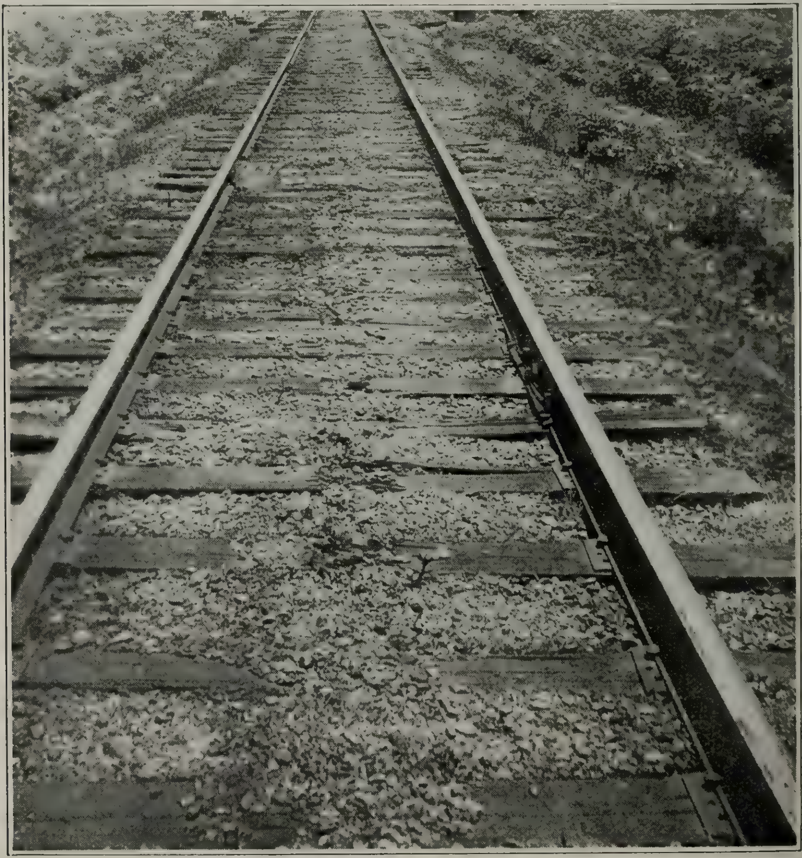

Fig. 6.—After Second Burning.

weed growth following the application of chemicals is not because of the sterilizing effect but rather the result of thoroughly killing all weed seeds and roots in the area treated.

The chemicals commonly used on railroads are sodium chlorate, calcium chlorate and sodium arsenate. The use of sodium chlorate creates a fire hazard because of the fact that it contains a large amount of oxygen. Sodium chlorate alone is not inflammable or explosive but in contact with combustible materials such as wood, dried plants and clothing it will burn furiously when ignited and will explode from friction or a blow.

Calcium chlorate creates considerably less of a fire hazard than sodium chlorate owing to the fact that it readily absorbs moisture from the atmosphere. It is available at the present time in commercial quantities only as a patented preparation equivalent to about 60 per cent pure calcium chlorate. It is not as effective pound per pound as sodium chlorate but is a more satisfactory material to use because of the lesser fire hazard.

Sodium arsenate has been used extensively for destroying weeds. Its principal objection is that it is very poisonous to both man and beast. When sprayed upon weeds it has a brackish, sweet taste that is attractive to grazing animals, and, therefore, it should not be used where there is a possibility of live stock getting access to it. It is also dangerous when used in powdered form because of the possibility of its being inhaled. It is also poisonous in contact with the hands or body.

Both chlorates and arsenates are effective on practically all types of vegetation, including the most troublesome perennials. Apparently the chlorates are more effective on root growth than the arsenate.

Oil

The application of oil to the surface of the roadbed has been primarily for the purpose of laying dust, although oil has also been used to a limited extent for the purpose of destroying weeds and retarding weed growth. Oiling the surface of the roadbed helps to form a crust which retards weed growth; it also has a sterilizing effect upon the ballast, particularly gravel ballast. The most effective results are reported with a mixture of creosote and distillate oils.

COST OF KILLING WEEDS

Figures showing the cost of removing vegetation from the roadbed, as a general rule, are of little value in comparing the results on different railroads or on different territories of the same railroad as the cost varies from place to place, depending upon the methods used, the climatic conditions, the period of cutting and the frequency and thoroughness of removal. The kind of ballast used is also a factor in determining the cost.

Exceptions may be made in such fixed operations as the operation of weedburners, mowing machines and ballast discers under conditions where the operating costs are not materially affected by the density of growth or other factors. With chemicals or oil, the amount used and the method of application vary to such an extent that cost figures are of little value.

Hand Weeding

The cost of removing weeds by hand varies from $25 to $125 a mile of single track per year. This wide variation is, of course, due to the fact that in some cases the removal of weeds extended from fence to fence while in other instances it included roadbed only, and in still others merely the ballast section. Cost figures are also affected by the number of weedings and the nature of the vegetation and the density of growth. The average cost, confined within the limits of the roadbed, approximates $70 per mile.

Steam Weed Destroyers

The cost of operating steam weed destroyers also shows a wide variation. As with hand weeding, the cost is affected by the density of the growth and the character of the vegetation. One road reports an average cost of operating three steam weed destroyers over 840 miles of track as $12.72 per mile for a single operation, including 35 cents per mile for royalty on the device used.

Flame Weed Burner

The cost of operating 18 self-propelled weed burners on five railroads is given in the following statement. These burners operated a total of 2017 days, burning 24,618 miles of track:

Gasoline, lubricants, fuel oil and supplies	$31,563.03	
Labor (including fire patrol)	54,788.66	
Operating Cost		$86,351.69
Interest and depreciation, 15 per cent on	$110,306.75	16,546.00
Maintenance (actual)		7,217.35
		$110,115.04
Cost per mile of single track burned, per burning, operation only	$3.51	
Cost per mile operation, interest, depreciation and maintenance	4.47	

Mowing Machines

The average cost of operating 16 mowing machines on 4 railroads a total of 852 days, mowing 11,107 miles of track, follows:

Gasoline, lubricants and supplies	$638.03	
Labor	14,812.81	
Operating Cost		$15,450.84
Interest and depreciation, 15 per cent on	$13,654.00	2,048.10
Maintenance (actual)		1,035.68
		$18,534.62
Cost per mile of single track mowed, per mowing, operation only	$1.39	
Cost per mile operation, interest, depreciation and maintenance	1.67	

Ballast Discers

The cost of operating 21 ballast discers on five railroads a total of 1,333 days, discing 10,068 miles, follows:

Gasoline, lubricants and supplies	$1,233.22	
Labor	35,262.10	
Operating Cost		$36,495.32
Interest and depreciation, 15 per cent on	$17,511.00	2,626.65
Maintenance (actual)		2,612.01
		$41,733.98
Cost per mile of single track disced, per discing, operation only	$3.62	
Cost per mile operation, interest, depreciation and maintenance	4.14	

Oil and Chemicals

Any figures that might be presented on the cost of applying oil or chemicals will be of little value, as they show an extremely wide variation. On one railroad the cost of applying chemicals ranges from $13 to $64 a mile, single application. The cost of applying oil shows a similar variation.

The cost of oiling roadbed varies from $30 to $130 per mile, depending upon the amount of oil used and the number of applications a year. One Western railroad has made two applications at a total cost of $200 per mile. The first application used 50 barrels per mile, at a total cost of $130; 25 barrels per mile were used on the second application, at a cost of $70 a mile.

Annual Cost

The costs of burning, mowing and discing secured from several railroads show remarkable uniformity, the variation in the cost of a single operation being less than 5 per cent. The foregoing cost figures apply to a single operation. It should be understood that several operations per year may be necessary to keep the track free from weeds.

The following figures on the annual cost of killing weeds are based on the experience of a railroad operating through the south and southwest, using burners, mowers and discers:

The estimated cost of keeping gravel ballasted track clean and free from weeds during a normal season by burning, mowing and discing in the southern states where weed conditions are most severe, is approximately as follows:

5 burnings per year @ $4.47	$22.35
3 mowings per year (track mower, single swath) @ $1.67	5.01
2 discings per year (finished work) @ $4.14	8.24
	$35.60

Eliminating the mowing, which is beyond the ballast section, the cost would be $30.59 per mile. During a year when the growth is exceptionally rapid and rank, which occurs frequently, the cost may be as high as $50 per mile.

To keep the same track and roadbed reasonably clean will cost as follows:

4 burnings per year @ $4.47	$17.88
2 mowings " " @ 1.67	3.34
1 discing " " @ 4.14	4.14
	$25.36

Eliminating the mowing beyond the ballast section will reduce this expense to $22.02 per mile.

In the same territory, with rock or other hard ballast, the cost will be as follows:

4 burnings per year @ $4.47	$17.88
3 mowings " " @ 1.67	5.01
	$22.89

Eliminating the mowing will reduce the cost to $17.88.

In northern and western Missouri, Kansas, Colorado and Nebraska the cost of keeping a gravel ballasted track clean is as follows:

4 burnings per year @ $4.47	$17.88
2 mowings " " @ 1.67	3.34
2 discings " " @ 4.14	8.28
	$29.50

Eliminating the mowing beyond the ballast section, the cost per mile is $26.16. In the same territory, with rock and other hard ballast, the cost would be:

3 burnings per year @ $4.47	$13.41
2 mowings " " @ 1.67	3.34
	$16.75

or $13.41 for the three burnings alone.

The following figures show the cost of burning, mowing and discing in Illinois and Iowa:

2 burnings per year @ $4.47	$ 8.94
2 mowings " " @ 1.67	3.34
1 discing " " @ 4.14	4.14
	$16.42

The cost of chemicals in the same territory, namely, Illinois and Iowa, follows:

Chemicals (one application)	$12.84
Mowing (two operations)	3.34
	$16.18

Omitting the cost of mowing from the above figures we have a cost of $13.08 per mile for burning and discing, and a cost of $12.84 for chemicals alone, which probably represents a fair comparison between the two methods of weed control.

Difference in the cost of weed control by different means do not reflect the superiority of any particular method. Each method has its field. Although the cost of one method may be greater than of another, the benefits from using such a method may be proportionately greater.

It is recommended that this report be received as information and the study be continued.

Appendix C

(4) GANG ORGANIZATION AND METHODS OF PERFORMING THE MORE COMMON TASKS OF MAINTENANCE OF WAY WORK

H. E. Kirby, Chairman, Sub-Committee; Lem Adams, C. W. Baldridge. F. J. Bishop. W. H. Brameld, Armstrong Chinn, William Elmer, H. H. Harsh, A. C. Harvey, C. A. Johnston, J. A. Parant, R. E. Patterson.

The subject of welding, as related to railroad track maintenance is of great scope and is rapidly assuming a major, definite position in the annual maintenance budget. At this stage of its development and application, however, its economic importance cannot be fully evaluated, but something of the magnitude of the work may be understood from the number of railroads which have adopted the practice during the last ten years. Although the economy of such conservation was demonstrated previously, economic conditions during the last five years have added impetus to the movement. This need became more evident as the speed of traffic and the weight of axle loads were increased, having the effect of producing more rapid deformation of rail-ends.

Several agencies are employed in restoring the ends of used rails in track, which processes are not within the province of this Sub-Committee other than to consider them in their relation to forces performing the work.

The processes of further hardening the ends of steel rails in track, known generally as heat-treatment, are likewise of importance to this study only as they require separate force organizations, or in their effect on welding forces when performed as an auxiliary function in combination with welding operations.

As with all expenditures, economy makes prerequisite a definite plan and program of welding, which should be prepared, checked and approved well in advance of the initiation of the work. The preparation of such a program for a given territory should follow an annual rail and welding inspection by the Division Engineer or similar chief maintenance officer on that territory. If left to the local track supervisor or subordinate, the proper general perspective will be lacking, and the program will be likely to reflect distorted conditions, since it is a natural tendency for one to magnify his particular problems in such circumstances.

This inspection will also permit the maintenance officer to determine and evaluate to a degree other factors related to welding, principal among which are:

(1) Condition of track superstructure:
  a) Surface; low joints; surface-bent rail.
  b) Underhead wear; rail and joint bars.
(2) General condition of substructure and roadway:
  a) Drainage: ballast, subgrade, lateral.
  b) Topography: crossings, adjacent station platforms, yards, other facilities.

It is important that the maintenance officer making a welding program exercise thorough knowledge of the limitations of welding as a remedy for rough-riding track. When it is doubtful whether or not to weld, the following may be considered:

(1) Under ordinary conditions on heavy traffic, high speed lines, rough riding track is practically never due entirely to battered rail-ends.
(2) Welding alone will do little toward changing the general profile of the track:
  a) Surface-bent rail will not be improved by welding.
  b) Poorly surfaced track will be affected but little.
  c) Dead track, lacking in elasticity, will not be livened.

The welding program should be considered in relation to other major work proposed for that year. It is particularly important that the welding program be coordinated with plans for new rail and surfacing. If the volume of these, especially the former, can be predetermined with reasonable accuracy for a longer period, say from two to five years, it may add further economy by conserving energy and materials.

The organization of forces to perform rail-end welding is subject to and dependent upon many variable conditions. These factors, governing progress and influencing the whole economy of the work, should be kept in mind as each project is being planned, labor allotted, and operating funds appropriated. They may be classified in the following manner:

(I) Factors contingent on general maintenance policy:
1) Whether by choice or necessity, a given railroad's general practice with respect to new rail purchases, and the resultant effect on:
  a) Life of rail in first location, and, the maintenance support given the rail in such new-rail territory: i.e., physical components of the track structure, and, surfacing, drainage, and so forth.
  b) The quality of the rail required, as determined by traffic and study, on the most important branch lines or non-new-rail territory; its standard of maintenance.
  c) The rail in less important branch lines and in yards and terminals.
2) The attitude of the railroad management concerning investment in modern machines for specialized work, particularly welding equipment and independently powered grinding machines.

(II) General factors:

1) The condition of the rail as a whole at the time the welding program is formulated:
    - a) The amount of battered or chipped rail and the time allowed in which to correct it, will largely be the limiting factors in determining whether out-of-face or spot work shall be used, and the number and size of the forces organized.
    - b) The depth of batter determined upon as the minmium which shall be welded, the length of batter, and the extent to which rail joints may be reshaped by up-setting, are important elements.
2) Heat treatment of rail ends at the time of welding.
3) Traffic: kind and amount.

(III) Factors of circumstance: local conditions:

1) Condition of rail-ends on the immediate job.
2) Track:
    - a) Single or multiple.
    - b) Topography and alinement: effect on visibility.
3) Traffic: Kind and amount.
4) Distance between camp headquarters and location of welding.

Four gang organizations, using the oxy-acetylene gas method of welding, are here presented. Each is predicated on the use of six welders, as this is the maximum number whose production under steady performance can be surface-ground by one grinding machine when this method of finishing is employed. These may be termed unit-gangs, of which the number required is determined by the volume of work, particularly with any necessary adjustments due to conditions peculiar to the job. They are used under ordinary conditions, on out-of-face work, where joints are to be cross-slotted, and it is assumed that the track will be put in satisfactory condition prior to the welding; that is, that section or other forces shall put all joints in good surface immediately in advance of the welding, and also apply new or reconditioned joint bars or shims and tighten or renew fittings as may be required.

Force A: Welding only; finishing with grinding machine

6 Welders
1 Grinder operator
1 Grinder operator helper
5 Laborers
1 Foreman

Estimated production, based on 6½ hours productive work: 240 joints per day. (6½ hours productive time out of an ordinary 8-hour day, with average heavy traffic, has been found to be a fair approximation.)

The operations performed by the welders require no detailed description. The grinder operator surface grinds the joints, and is responsible for the grinding machine, which he keeps in repair; the grinder operator helper operates the cross-grinding machine, and assists generally. Laborers' duties include handling gas cylinders, unloading full, loading empty, storing, transporting to and from the job, placing them in position for use as the gang progresses; helping grinder operator as may be required; any necessary flagging; oiling joints, where practiced; and carrying drinking water.

Force B: Welding and heat-treating; finishing with grinding machine

6 Welders
1 Grinder operator
1 Grinder operator helper
7 Laborers
1 Foreman

Estimated production, based on 6½ hours productive work: 210 joints per day.

The operations of this gang differ from gang A only by the addition of the heat-treating process. This treatment is given the rail-ends in the prescribed manner by the welders immediately upon the completion of the weld, before the metal has cooled. Two additional laborers are provided to keep the water barrels filled, to carry buckets to fill quenching dippers, and to assist in quenching.

Force C: Welding only; finishing with flatters

6 Welders
6 Welder helpers
2 Laborers
1 Foreman

Estimated production, based on 6½ hours productive work: 180 joints per day.

By this method, which employs more fully the practice of forging, the welders hammer the deformed rail-end at fusion temperature back to true surface, adding new metal only where required. The helpers assist in this sledging, and in cross-slotting joints with a hot-cut chisel; they also make manifold and cylinder connections. The duties of the laborers are the same as with gang A.

Force D: Welding and heat-treating; finishing with flatters

6 Welders
6 Welder helpers
3 Laborers
1 Foreman

Estimated production, based on 6½ hours productive work: 150 joints per day.

This organization functions in the same manner as gang C, except that heat treating is added to its duties. One extra laborer is assigned to assist generally, and specifically to help provide quenching water.

Based on the foregoing estimates of production, and on the following assumption of rates, including charges covering operation, maintenance and depreciation of equipment not common to both methods of finishing the weld, the labor cost for the four gangs would be:

Assumed Rates

Welder	$ .70 per hour
Welder Helper	.50 " "
Grinder Operator	.70 " "
Grinder Operator Helper	.50 " "
Laborer	.40 " "
Foreman	.87 " "

	Estimated Labor Cost		
	Daily Cost	Production	Unit Cost
Force A	$78.56	240 rail joints	$0.327
" B	84.96	210 " "	0.405
" C	71.26	180 " "	0.396
" D	74.46	150 " "	0.496

As work is begun, gas cylinders should be distributed at 200 ft. intervals over 1000 ft. of track. The welders, working in series, torches equipped with 100 ft. of each gas hose, start one each at the ends of the six 200-ft. segments and work in a forward direction. Thus, when each welder has covered the 200 ft., 1200 ft. of track, or from 61 (39-ft. rail) to 73 (33-ft. rail) rail joints, will have been completed. The whole force then advances, and the process is progressively repeated.

It is estimated that each welder will use approximately 90 cu. ft. of each gas per hour, or about 15 cylinders of each will be the daily consumption of the gang. The acetylene complement should preferably consist of two cylinders connected by manifold. The day's supply of gas should be delivered to the job in the morning, and all empty cylinders taken back at the end of the day. The force will use one heavy-duty motor car, one trailer car, and two or more flat-deck trailers to transport men, equipment and materials.

Forces should be provided with outfit cars, comprising living quarters, two material cars, one each for storing oxygen and acetylene, one equipment car for transporting the motor car, trailers, grinding machines and other equipment, one end of which should have a built-in work bench for making light equipment repairs. If heat-treating is being done, the force should be furnished a retired locomotive tender, or a tank mounted on a flat car, to supply quenching water.

Quality of workmanship is the most important feature of welding. The durability of the weld will determine the economy of the method employed. The cost figures given here are based on the best available data, but are not necessarily indicative of the relative economy of different methods.

Conclusions

(1) A welding program for a given division or local territory should be based on knowledge secured from a personal inspection of rail by the chief maintenance officer of that territory.

(2) Welding work should be coordinated with other maintenance operations, particularly with respect to new rail and surfacing.

(3) Efficient utilization of modern equipment and the introduction of new methods can be brought about most economically by a gang organization designed specifically for such equipment.

(4) The work should be adequately supervised, and periodic checks made to determine:

(a) If proper organization of forces is being followed.
(b) If welding is being performed according to specifications.
(c) When heat-treating, if desired rail hardness is being secured without injury to the rail.

Recommendations

That this report be received as information and the subject be reassigned for further study.

Appendix D

(5) OUT-OF-FACE RENEWAL OF TRACK IN VIEW OF THE INCREASING LIFE OF BASIC UNITS OF TRACK CONSTRUCTION

G. M. O'Rourke, Chairman, Sub-Committee; Lem Adams, C. W. Baldridge, J. I. Catherman, K. H. Hanger, G. M. Magee, J. B. Martin, F. N. Nye, J. A. Parant, F. H. Rothe, J. R. Watt, C. R. Wright.

Your Committee was instructed to ascertain practices on American railways and those of foreign countries in renewing the track structure in its entirety and to determine what, if any, economies in labor are effected by such maintenance practice.

Early in 1934 inquiries were addressed to a number of the larger carriers of this country and those of England, Germany, France, Italy and other countries.

The replies received from American railways are to the effect that, except for a few test sections where GEO track construction was laid and in some instances where tracks lie in paved streets, the practice of complete out-of-face renewal of the entire track structure has not been followed.

One railroad in Kansas, originally constructed in 1886, renewed or reconstructed out-of-face, twenty miles of single track in 1910–1911. The track structure from the subgrade up was replaced. Further inquiry is being made as to labor saved in maintaining this track compared with cost of maintaining track not so renewed.

The Committee did find that the practice is carried on regularly in Europe and quotes below from an address before the Roadmasters' Association by John V. Neubert, Chief Engineer Maintenance of Way, New York Central Railroad, and published in Railway Engineering and Maintenance for October, 1930, page 448:

> "From my observation, the general maintenance program is quite different from that in America. For example, an estimate is made of the average life of the entire track structure, and the life of the rail is based on this average. A schedule is then set up as to the amount of rail to be renewed and the entire track structure, rail, ties and fastenings, is taken up, the roadbed smoothed down and new material put in its place. The mileage set up for renewal depends upon the new rail schedule and the general condition of the track in the territory on which it is to be installed. While this work is being performed, traffic is detoured over other tracks, so that it is possible to get full-time use of the track while they are replacing the roadbed and track. Most of the railroads in Europe consist of two or more main tracks, and this makes it possible to detour trains to facilitate the maintenance work. In detouring trains for work of this character, a schedule is set up between the various departments, so that it can be done at the most advantageous time with the least interruption of train service, and with the greater economy.
>
> "When a new line is built in Germany, the roadbed is rolled as it is constructed, ballast is then unloaded and, after it is spread on the subgrade, it is rolled to a hard surface before the ties are placed and the track constructed. Next, loose stone is applied, sufficient for a slight surfacing lift and the necessary filling and dressing. When the track is put into service on the new roadbed, it is possible to operate at schedule speed within a very short time, a maximum of two days, I was told.
>
> "When track is replaced out-of-face in this manner, it rides smoothly, as one might expect. But the work is not followed up with periodic programs of general surfacing as is generally done in America. With the lighter axleloads and lighter total tonnage, this possibly may not be required as it is here."

From an article on French maintenance practices, by Sir Gordon Hearn of the British Permanent Way Institute, published in Railway Engineering and Maintenance for July, 1930, page 455, is quoted below:

> "Equipment for renewing track, consisting of a gasoline motor car as the power unit, four low rail gantries for carrying double (spliced) rail lengths, four ballast hopper cars and a low-sided truck for carrying fastenings, was demonstrated on the Paris, Lyon & Mediterranean. This equipment carried sufficient material for laying 650-ft. of track. By means of auxiliary wheels which run on channel irons, the motor car can be derailed and pushed to one side in about 6 or 7 minutes. While this equipment has its advantages when used on busy tracks, the material must be handled twice from the material train to point of use, which is a disadvantage."

This is the extent to which the Committee was able to secure data as to their maintenance practices.

The Committee wishes to express its appreciation of the courtesy extended by C. E. R. Sherrington, Secretary of Railways, Research Service, London, and Dr. Theodor Buchholz, Consulting Engineer, Berlin, in furnishing much of the data incorporated in the following report.

MAINTENANCE AND RENEWAL PRACTICE IN GERMANY

The standard form of main line track construction in Germany conforms in general to the following description:

Roadway.—The roadway shoulder extends 9-ft. 4-in. (2.85 m.) beyond the center line of outside track. The roadway surface is sloped 1:25 from its center or crown in both directions to afford suitable drainage. Adequate side ditches are provided through cuts. Particular attention is given to securing proper drainage.

Ballast.—A good grade of rock ballast is used consisting of materials such as diorite, basalt, melaphyr, porphyry, greywacke, or quartzite. The individual stones are cubical in size with sharp edges and range from 3 cm. (1.18 in.) to 6 cm. (2.36 in.) in size.

The ballast is generally 18 inches in depth below the bottom of the tie at the center line of track and the ballast shoulder extends 1.60 meters (5 ft. 4 in.) outside of the center line of track. The ballast is left below the tie centers to prevent center binding and is placed above the rail base to minimize temperature variations.

Kind and Size of Ties.—Softwood ties (pine, larch) are used on tangent track and hardwood ties (oak, beech) on very pronounced curves. All ties are adzed, bored, and treated, mostly with creosote. A considerable number of steel ties are used, but are not as satisfactory as wood, due to shorter life, noise attending train passages, and difficulty of insulation. The size of tie is 26 cm. (10.23 in.) wide, 16 cm. (6.3 in.) high, and 260 cm. (8.53 ft.) long. The two upper edges are beveled to permit securing a better utilization of tie timber in forming the ties.

Tie Spacing.—A double tie, consisting of two ties bolted together, is used at the rail joints, which are opposite each other and not staggered as in the American practice. Between joint ties there are 45 intermediate ties per 98.4 ft. rail. The average spacing of the intermediate ties is 25½ inches, the ties next to the joint ties being spaced somewhat more closely. The purpose of the double joint tie, and closer spacing at the joint is to give added rail support to compensate for the reduction in rail stiffness and strength at the joint.

Tie Plates and Rail Fastenings.—The GEO form of construction is used consisting of a heavy tie plate 6-19/64-in. wide by 13-37/64-in. long which is independently fastened to the tie at the treating plant by four screw spikes. The tie plate is provided with large double shoulders, between which a poplar wood shim and the rail base rests. Two special clamp fastenings secure the rail firmly to the tie plate.

Rail and Joint Bars.—The standard rail section weighs about 100-lb. per yard. The rail joint bars are of the symmetrical type with four hole drilling.

Length and Classification of Trackage.—The German National Railways have 31,500 miles of track of the first-class, which includes all lines having high speed passenger service, heavy and frequent freight traffic, or terminal trackage receiving heavy use. On all tracks of this class, the out-of-face method of track renewal is employed.

To tracks of the second-class, belong the remaining main tracks of light traffic main lines and branch lines, passing tracks, arrival and departure freight lines, and important terminal tracks. The total track mileage of this class is 29,600 miles. The method of maintenance on these tracks is to make repairs with suitable material released in connection with renewal of first-class trackage.

The remaining side tracks, which are subjected only to occasional loads, with a total track mileage of approximately 13,500 miles, comprise the tracks of the third-class. These tracks are repaired with material released from first-class tracks not suitable for use in second-class tracks or with material released from second-class tracks in the course of its repair.

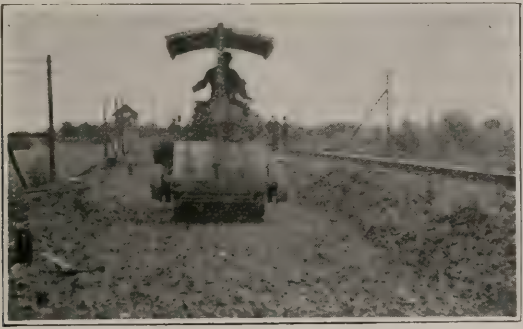

Fig. 1.—Gasoline Roller Compacting Ballast Preliminary to Laying New Material on the German National Railways.

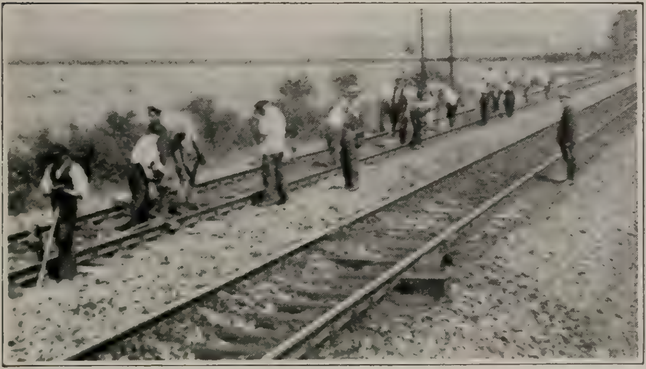

Fig. 2.—Surfacing Gang Making an Out-of-Face Periodic Surfacing. Pick Tamping the Ties on the German National Railways.

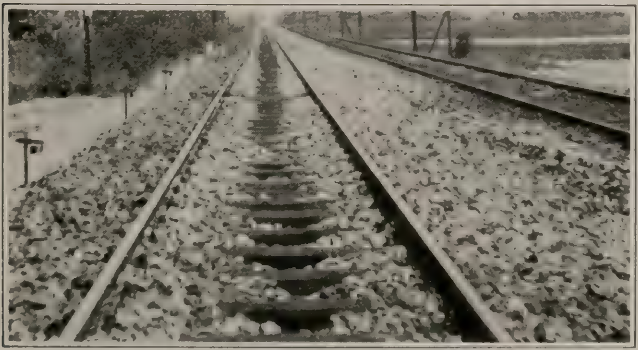

Fig. 3.—Track After Final Lining and Dressing and Out-of-Face Surfacing. Ballast is Placed Around Rail Base to Reduce Temperature Variation. On the German National Railways.

Out-of-Face Renewal on First-Class Tracks.—Tracks of this class carry generally a traffic density of from 10 million to 20 million gross tons per year, although in some specific locations the traffic density is greater. The general plan is to renew all the material in the first-class tracks every 15 to 20 years depending on the traffic density. This requires an average renewal of about 2000 track miles per year.

In making the track renewal, all the old material down to the ballast is removed and graded for use in second or third class tracks. This applies to ties as well as rails and fastenings. The old ballast is then thoroughly cleaned and new ballast added as required. The ballast is then leveled by hand and compacted by rolling with a power roller. The rolled surface is finished to about 2 inches below the final grade of the bottom of the ties.

New material is assembled and placed in position. All new ties are used with new plates applied at the treating plant. The rail is laid and the clamps tightened. Additional ballast is then added, and the track given a 2 inch raise to final grade and lined. Permanent markers for both grade and alinement are provided. The rail is laid with ⅛-in. tight gage. The inside rail on double track is about 3/16-in. lower than the outside rail to compensate for the added ballast support. The joints are surfaced ⅛-in. high and it is claimed this reduces the tendency to batter. The ballast section is dressed as indicated in the accompanying photographs leaving the ballast low at the tie center to prevent binding and placing the ballast about the rail base to reduce the variation in rail temperature.

A few weeks following the track renewal, all clamp bolts, joint bolts, and screw spikes are tightened to take up initial seating.

Every two to four years, depending upon the traffic density, the first-class tracks are surfaced out-of-face.

The fastenings are first tightened, the cribs forked out, the track raised and tamped, old ballast forked back and new ballast added, the track lined and dressed. This work is so thoroughly done that practically no maintenance work is required between the resurfacing intervals. The accompanying photographs show a typical surfacing gang at work on a periodic out-of-face surfacing.

Advantages of Out-of-Face Renewal.—The advantages claimed for the out-of-face renewal method are better track condition and more systematic and economical maintenance. The use of all new material in the first-class tracks keeps these tracks in the best possible condition. The use of released material in tracks of the second and third class provides a standard of maintenance, and in renewal cost lines up with the lower traffic use.

It is also contended that the riding condition of track is much superior when it is thoroughly conditioned at intervals and not disturbed during the intervening period when it is continually being torn up and disturbed from time to time by spot-in renewals.

As a result of the systematic method of renewal and maintenance it is also contended that track labor economies are effected through specialized direction of labor. All track work is done by piece work. Since all work is so well systemized it is comparatively simple to establish piece-work rates for performance of the work.

MAINTENANCE AND RENEWAL PRACTICE IN ENGLAND

The standard form of main line track construction in England conforms generally to the following description:

Roadway.—On both cuts and fills the roadway has a 30-ft. crown for double track and an 18-ft. crown for single track. The roadway is sloped about 1:30 each way from the center. Careful attention is given to securing adequate side ditches and drains through cuts.

Ballast.—A sub-ballast consisting of 4 to 6 in. of clean, fine ashes is used.

On fills the top ballast consists of 4 in. of crushed rock less than 2 in. in size under the ties. Between this and the sub-ballast is an 8-inch depth of cinders.

On cuts the same sub-ballast and top ballast are used with 8 in. of crushed rock or slag over the sub-ballast. This intermediate ballast ranges in size from 2 to 4 in.

Kind and Size of Ties.—All ties have been treated in England since the opening of the Liverpool and Manchester Railway in 1830. Most of the ties are imported from the Baltic, and are commonly known as Archangel timber, which is classed as soft wood.

The standard size of the tie is 5-in. × 10-in. and the ties are placed with the flat side down. On the newest construction, two 5-in. × 12-in. joint ties are used to give added support at the joint.

Tie Spacing.—The ties are spaced 24 to a 60-ft. rail. This gives an average spacing of 31 in. for intermediate ties. The joint ties are spaced 24 in. for the older construction and 14 in. for the newer construction using a very short joint bar.

Tie Plates and Rail Fastenings.—The tie plate consists of a heavy cast iron rail chair weighing 46 lb. independently secured to the tie by three lag screws, two of which are on the inner side. The base of the chair is 8 in. in width and 14½ in. in length. The chairs support the rail which is held in position generally by means of hard wood wedges driven between the outer side of rail web and the chair. A special fabricated steel wedge has also been used on a small scale.

Rail and Joint Bars.—The standard rail for first-class main track weighs 95-lb. per yard and is of the bullhead type. The standard length of rail is 60-ft. The rail joints are of the symmetrical type, and the old standard length was 18 in. with four 15/16-in. diameter bolts. Recently, a bar 9 inches in length, with two bolts, has been installed experimentally with satisfactory results and may become the new standard. The purpose of the short bar is to permit a closer tie spacing at the joint.

Traffic Requirements.—The weight of rolling stock may be taken as follows:

Main line passenger or freight locomotives, inclusive of tender, 100 to 150 long tons, in working order.
Maximum axle load 22 long tons
Passenger cars (steam) 27 to 40 long tons.
Freight cars, tare weight 6 to 20 long tons.

There is no speed limit and express trains regularly attain 80 to 90 miles per hour. The majority of freight trains are only equipped with hand brakes, the average carrying capacity being 10 to 11 long tons. Some freight trains, if fully air-braked, attain 60 miles per hour.

Statistical records are not kept to show the gross ton-miles carried over the tracks, and averages only are kept for net ton-miles. British trains are comparatively light. The freight trains average about 45 cars with a gross weight of 300 to 500 long tons. Passenger trains vary widely from two car trains of 50 tons to 19 cars of 600 tons.

On main track lines, approximate calculations indicate the traffic will vary generally from 10 million to 20 million gross tons per year.

Out-of-Face Renewal on First-Class Tracks.—It is the practice to renew tracks of the first-class about every twenty years, using all new rails and fastenings, rail chairs, ties, and ballast as required. The tracks are thoroughly reconditioned at this time and generally no out-of-face surfacing is required for the next twenty-year period. General maintenance work and occasional spot-surfacing are performed when necessary.

Rail and ties released from main line tracks are salvaged for use in other tracks. In this way an average tie life of 33 years is obtained from softwood ties.

Advantages of Out-of-Face Renewals.—With respect to the advantages and economies of the out-of-face renewal system, the following quotation is taken from the reply of Mr. Sherrington:

> ". . . Our Chief Engineers consider the out-of-face renewal system far more satisfactory than the alternative systems since . . . it disturbs the track less. In these days of economy it is essential to obtain the maximum life possible from both ties and rails, and as this maximum life of both cannot in general coincide, out-of-face renewals are nowadays reserved for the most important main lines only."

Conclusions

According to the investigations made by the Committee, the principal difference between American and European practice lies in the matter of out-of-face renewals of ties and out-of-face surfacing to replace spot surfacing. For many years American railways have replaced rail and fastenings out-of-face as is done in the European countries. It is the opinion of the Committee that out-of-face renewals of ties in European countries has largely been made economical and practical as a result of the longer tie life and control of mechanical wear secured by use of relatively large tie plates, independently and securely fastened to the ties. It is further the opinion of the Committee that the practice of out-of-face surfacing maintenance is made practical and economical in these countries as a result of the well drained and compacted roadbed, and of the high relative strength of track structure compared to the wheel loadings. The Committee wishes to draw attention, in this connection, to the increasing practice in recent years on many American railways of performing out-of-face surfacing every three to four years on heavy track sections, making all tie renewals that would be required prior to the next surfacing period.

Recommendations

Your Committee recommends the subject be continued for study of relative labor economies of American and European practices; this report to be received as information.

Appendix E

(7) ECONOMIES IN TRACK LABOR TO BE EFFECTED IN THE MAINTENANCE OF JOINTS BY WELDING AND THE USE OF REFORMED BARS

W. R. Bennett, Chairman, Sub-Committee; Lem Adams, F. J. Bishop, William Elmer, W. O. Frame, W. S. Hanley, H. H. Harsh, J. B. Martin, F. N. Nye, G. M. O'Rourke, P. T. Robinson, W. H. Vance.

Your Committee has contacted a number of railroads with the intent of developing the extent to which track labor is affected as the result of rail-end welding and the use of reformed bars. Unfortunately, very few railroads have cost data reflecting the desired comparisons. From information at hand, it is apparent that appreciable labor economies may be anticipated, but the extent to which they may be expected has not been determined. Your Committee therefore wishes to continue the subject for further study.

Appendix F

(8) EFFECTS OF RECENT DEVELOPMENTS IN MAINTENANCE OF WAY PRACTICES ON GANG ORGANIZATION (SUCH AS USE OF HEAVIER RAIL, TREATED TIES AND LABOR SAVING DEVICES WHICH MAKE PRACTICABLE SMALL SECTION FORCES, AND CONDUCTING THE MAJOR PART OF MAINTENANCE WORK WITH EXTRA GANGS)

G. M. Magee, Chairman, Sub-Committee; F. J. Bishop, W. H. Brameld, W. O. Frame, K. H. Hanger, W. S. Hanley, Elmer T. Howson, C. T. Jackson, H. E. Kirby, R. E. Patterson, P. T. Robinson, F. S. Schwinn.

Three previous reports on this assignment have been presented to the Association by the Committee. These may be found in the Proceedings, Vol. 32 (p. 194–197); Vol. 33 (p. 385–390); and Vol. 34 (p. 102–104).

During the period from 1922 to 1930, railways generally improved their track structure with heavier rail, additional and larger tie plates, treated ties, additional ballast, etc. Attention was also given to improvements in roadway drainage by widening cuts, placing rock and pipe drains, etc. Many units of labor-saving equipment were developed and placed in service. As a result of these improvements several railways have reduced the items of routine maintenance to a minor place and handle the major items in a more carefully planned, systematic, and efficient manner. The development of labor-saving equipment to perform many items of maintenance has required specialized organizations for its most efficient use. The more efficient utilization of labor under mass production planning with each worker performing a special task has been an additional influence. As a result of these factors there is a very marked trend towards the delegation of less work routine to section gangs and the diversion of such work in a systematic manner to specialized gangs equipped with efficient labor saving devices.

Previous reports have described the changes in maintenance practices which have been put into effect by those railways which have pioneered in the reorganization of their maintenance forces along these lines. It was thought that it would be of considerable value this year, two years having elapsed since the last report, to give the Association the benefit of the experience of these pioneer roads with their reorganizations, including any further changes, improvements, or extensions in the methods reported. In addition, information has been obtained from certain other railways which have made extensive reorganizations since the last report.

This subject is important at this time. Through the depression, maintenance forces and section gangs in particular have been reduced to minimum. If we may assume that we are nearing the time when maintenance allowances will be increased the logical plan will be to make that increase through the addition of specialized gangs and not in additional section forces *if the specialized gang provides the most efficient method of maintenance.*

Chicago, Milwaukee, St. Paul & Pacific Railroad (p. 386, Vol. 33)

The present permanent organization of this railway consists of 939 section and yard gangs, with an average of 16.12 miles of main and sidetrack assigned to each. The average number of laborers for eight-hour day per gang during the first nine months of 1935 was 2.79. These gangs performed ordinary maintenance work of the emergency class and renewed 1,114,104 cross-ties.

From about June 1 to August 31, and in some instances later, specialized gangs were used for tie renewals and maintenance work. Twenty-two "Tie Gangs" of from 23 to 133 men each renewed ties and lined the track. These gangs used no new ballast except where required by scant ballast section. These gangs were equipped with 8-tool tamping machines. Five "Maintenance Gangs", varying in size from 40 to 127 men, made a light ballast raise, renewed and straightened ties, surfaced, lined and gaged track. These gangs were equipped with power jack, 8-tool tamping machine, and ballast dressing machine. Tie and Maintenance Gangs renewed 1,850,494 cross-ties.

The "Rail Renewal" gangs consist of approximately 150 laborers, equipped with:

2 cranes for unloading rail
4 spike pulling machines
4 adzing machines
1 rail laying machine
2 power drills
2 bolt tightening machines
2 rail loaders

The "Ballasting Gangs" consist generally of 350 laborers, equipped with:

2 spike pullers
1 power jack
2–8 tool tamping machines
1 ballast plow
1 ballast dressing machine

These gangs renew ties as required.

Angle bars are renewed by system gangs equipped with bolt tightening machines. Routine bolt tightening is performed by a system gang operating a battery of four bolt tightening machines. Another system gang builds up battered rail-ends and heat treats new rail-ends.

Weeds are killed chemically and Jordan ditchers are used to clean out cut ditches.

The Pennsylvania Railroad (p. 387, Vol. 33 and p. 102, Vol. 34)

No further changes have been reported.

Great Northern Railway Co. (p. 388, Vol. 33 and p. 103, Vol. 34).

No change has been made in the organization described. The small floating maintenance gang assigned to each Roadmaster's district, which is equipped with up-to-date power tools, has given satisfaction, and the demand from Roadmasters for gangs of this type has rapidly increased.

Boston & Maine Railroad (p. 388, Vol. 33 and p. 103, Vol. 34).

The maintenance practices previously described are still in effect and are resulting in very satisfactory economies. All track walkers have been replaced by motor patrols except in large terminal yards. These patrols consist of a foreman and one laborer who cover from 35 to 100 miles of track daily on a light inspection car.

Missouri Pacific Lines in Texas and Louisiana (p. 389, Vol. 33, and p. 103, Vol. 34)

Bolt tightening gangs have been organized consisting of 4 men with 2 power wrenches each. These gangs average 4 miles per day and each have been assigned to approximately 600 miles of main line. Section forces in these territories are no longer required to tighten bolts except in an emergency. No further changes are reported.

Chicago, Burlington & Quincy Railroad (p. 103, Vol. 34)

This railway has extended its reorganization plan to include all but a small part of its mileage and is well-satisfied with the results. It is considered that most efficient and economical trackwork can be done, in general, by using small section gangs of one foreman and three men for policing and minor maintenance work; floating gangs of 15 men each to handle the heavier routine maintenance work; and large extra gangs to handle rail laying, reballasting, grade raising, etc.

Delaware, Lackawanna & Western Railroad (p. 103, Vol. 34)

This railway has found its maintenance reorganization plan using specialized maintenance gangs satisfactory. The work is done better and the number of locations reduced where track is being raised, tied, and surfaced which materially reduces the interference with traffic.

Erie Railroad (p. 104, Vol. 34)

This railroad is well satisfied with its reorganization using specialized gangs and reports a very substantial improvement in the efficiency and performance of tie tamper gangs in 1935 as compared with 1931. Any increase in maintenance allowance will be alloted to the specialized gangs rather than to section forces.

Lehigh Valley Railroad (p. 104, Vol. 34)

No changes in maintenance methods or practices have been made since the previous reports.

Chicago, Rock Island & Pacific Railway

This railway has completely reorganized its track maintenance forces and methods of supervision. This has been done by increasing the length of sections, from 6 and 8 miles, to from 9 to 12 miles. The lengths of Roadmasters' districts have also been increased, eliminating about one district on each Superintendent's division.

Track inspectors were appointed, reporting to the Roadmasters and given 60 to 70-mile territories which they cover daily in one direction on light inspection motor cars. This inspection service relieves the section foremen of normal track patrol duties. In addition, the inspector frequently examines bridges and culverts, attends to switch lamps, paints switch targets and derails, applies missing bolts in switches and frogs, and performs other similar light work. He also looks after the details of the section work, coordinating such work on the different sections and acting as a liaison officer between the Roadmaster and the section foremen.

This inspectorship system has been extended over the entire line with the exception of a small percentage of heavy curvature territory. The railway is well satisfied with the results obtained from the increased supervision and improved efficiency of the track organization. A full account of this railway's maintenance organization was published in the October, 1932, issue of Railway Engineering and Maintenance.

Southern Pacific Company

This railway reports the use of large system gangs for rail laying, the gangs being completely outfitted with rail cranes, spike pulling machines, adzing machines, pneumatic wrenches, spike drivers and drills. More efficient and satisfactory work has been obtained from these large specialized gangs. Turnout and stock rails are drilled and bent at the shops with considerable economy.

Specialized system surfacing gangs are used in connection with rail relaying. These gangs are equipped with pneumatic tampers. Considerable spot surfacing has been done by section gangs using 2 and 4-tool pneumatic tamping equipment.

New York, New Haven & Hartford Railroad Co.

Two years ago, all sections on the four-track electrified line between New Haven, Conn., and the New York terminals were eliminated. The results obtained from this change were so satisfactory, representing a considerable saving in money and an increase in production, that on June 1, 1935, all remaining sections on the system were eliminated, and gangs without definitely defined territory were substituted. The new organization consists of 138 track gangs, including 51 large heavy-work gangs, 58 spotting gangs and 29 yard gangs. This compares with the former total of 292 gangs. The larger gangs consist of 10 to 15 men each; the spotting gangs of 4 to 6; and the yard gangs of 6 to 20 men each. At the time the change was made, 51 new motor trucks were purchased, one of which was assigned to each of the heavy-work gangs, and these are in addition to 49 trucks already used to transport the men to and from work and to handle tools, materials and supplies when not transporting men.

The heavy-work gangs make all main-line tie renewals, do all out-of-face surfacing and lining, clean and renew ballast, lay rail, mow the right-of-way, do the necessary ditching and tighten bolts. The spotting gangs are routine light-maintenance gangs, confining their operations to spot surfacing, spot joint maintenance, policing and emergency repairs and renewals, generally on territory where the larger gangs do not work during the current year. The yard gangs, as their name implies, are confined to yard maintenance, although in a few special cases they care for a small amount of main track in addition.

Under this new system of organization, the system of track patrol has, of necessity, been revised. Section track walking has been abolished and 12 foot patrols and 40 motor-car patrols have been substituted, all of whom report directly to the respective supervisors.

Results indicate a substantial decrease in the cost of supervision, overtime, nonproductive time, and work train service and in addition, a considerable increase in efficiency and production. A full account of this railroad's track maintenance organization was published in the December 7, 1935, issue of Railway Age.

Wichita Valley Railway

In August, 1932, this railway began a reorganization of its maintenance forces. Formerly the maintenance organization consisted of sections approximately 10 miles in length with a section foreman alone during short seasons and a foreman with two or three men during the working season. Under the new plan, the sections were lengthened to about four times the former length. A track inspector patrols the section daily with a light inspection motor car and inspects switches, track, bridges, culverts, etc., takes care of small jobs, makes emergency repairs, and reports track conditions daily to the foreman. The foreman is thus relieved of miscellaneous tasks and with a gang of about 8 laborers follows a working schedule throughout the season as outlined by the Roadmaster.

This organization with considerably reduced expense has been able to make substantial improvement in the condition of the property. For a more detailed account of the organization, reference may be made to the September 21, 1935, issue of Railway Age.

Conclusions

Improvements made in the track structure during the years from 1922 to 1930 have reduced the routine maintenance work and permit the delegation of heavy maintenance in a systematic manner to specialized gangs fully equipped with labor-saving devices with resulting economies.

Recommendations

The Committee recommends that this report be received as information and the assignment be continued for further study.

Appendix G

(9) COMPARATIVE COSTS OF MAINTAINING TRACK ON VARIOUS KINDS AND DEPTHS OF BALLAST

Armstrong Chinn, Chairman, Sub-Committee; W. R. Bennett, W. H. Brameld, H. A. Cassil, Wm. Elmer, K. H. Hanger, H. H. Harsh, Elmer T. Howson, H. E. Kirby, F. H. Rothe, F. S. Schwinn, H. M. Stout, J. R. Watt.

This is a new subject and the Committee has been unable, so far, to find any railroad that keeps its records and cost data in such shape that a proper answer to the assignment can be developed. Information has been received from several railroads but all of it has been of a general character and could not be used in a definite way. This information indicates that, for the roads reporting, maintenance of way operations involving ballast can be carried out more cheaply in cinder, chat and gravel ballast than in crushed stone or slag ballast, but it did not show how frequently these operations are required for the various kinds of ballast.

The proper depth of ballast is outlined on page 102 of the Manual. For any particular ballast the most economical maintenance should result when the track is carried on a depth that will produce approximately uniform pressure on the roadbed. It is felt that a greater depth will have very little effect on the cost of maintenance involving ballast operations while a lesser depth will increase the cost so greatly that few main tracks are now carried on ballast of insufficient depth. One road in reporting stated, "The term 'depth of ballast' is very vague. On a road that has been in existence for any length of time this depth can be measured in feet instead of inches. Just where the dividing line between ballast and roadbed lies is difficult to determine". For these reasons the Committee feels there is no object in continuing the study of that part of the subject dealing with the depth of ballast.

This report is submitted as a progress report and the Committee recommends that the subject be changed to read, "Comparative Costs of Maintaining Track on Various Kinds of Ballast", and reassigned for further study.

REPORT OF COMMITTEE XV—IRON AND STEEL STRUCTURES

G. A. Haggander, *Chairman;*
James Aston,
P. S. Baker,
F. E. Bates,
J. E. Bernhardt,
Adolph J. Buhler,
A. W. Carpenter,
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G. L. Staley,
H. C. Tammen,
G. G. Thomas,
G. H. Tinker,
G. H. Trout,
F. E. Turneaure,
F. P. Turner,
H. T. Welty,
W. G. Williams,
A. R. Wilson,
W. M. Wilson,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual: The Specifications for Steel Highway Bridges, and Rules for Rating Existing Bridges should be revised to be consistent with the revision of the Specifications for Steel Railway Bridges (Appendix A).

(2) Application of and specifications for fusion welding and gas cutting for steel structures, collaborating with ASTM Committee A-1, on Steel. Progress in study. No report.

(3) Impact-Railway Bridges: Recommendations of this Sub-Committee are incorporated in the Rules for Rating Existing Bridges. A part of the work under this assignment was included in the Specifications for Steel Railway Bridges, adopted in 1935. The Committee is continuing its study of impact on ballasted deck steel bridges and short span steel bridges.

(4) Design for Rivet Heads for Steel Structures. Progress in study. No report.

(5) Stresses in Wire Ropes Bent Over Sheaves. Progress in study. No report.

(6) Different Grades of Bronzes to be Used for Various Purposes in Connection with Iron and Steel Structures. Progress in study. No report.

(7) Design of Expansion Joints Involving Iron and Steel Structures. Progress in study. No report.

(8) Design of Tension Members and Connections in which Rivets Develop Tension. Progress in study. No report.

(9) Effect of Proposed Increase in Vehicular Weights on Highway Bridges. No report.

(10) Review specifications for overhead highway bridges of the Association of State Highway Officials insofar as they relate to steel construction. Progress in study. No report.

The Committee on Iron and Steel Structures,
G. A. Haggander, *Chairman.*

Bulletin 382, December, 1935.

Appendix A

(1) REVISION OF MANUAL

O. E. Selby, Chairman, Sub-Committee; J. E. Bernhardt, C. H. Chapin, O. F. Dalstrom, C. S. Heritage, P. B. Motley, I. L. Simmons, C. E. Sloan, G. H. Trout, R. A. Van Ness, A. R. Wilson.

Your Committee recommends elimination from the Manual of the material under "Copper-bearing Steel for Structural Purposes", appearing in Supplement to the Manual, 1932, Bulletin 347, page 41.

Also elimination of the "Rules and Unit Stresses for Rating Existing Bridges," on pages 1248 to 1250 inclusive, of the current Manual, and substitution therefor of the following "Rules for Rating Existing Iron and Steel Bridges."

The revision of these rules was the work of the following Special Sub-Committee: B. R. Leffler, Chairman, Sub-Committee; F. E. Bates, A. W. Carpenter, C. H. Chapin, O. F. Dalstrom, Otis Hovey, J. B. Hunley, H. S. Loeffler, P. B. Motley, C. S. Sheldon, C. E. Sloan, S. M. Smith, G. H. Tinker, G. H. Trout, F. E. Turneaure.

RULES FOR RATING EXISTING IRON AND STEEL BRIDGES—1936

Carrying Capacity

1. The carrying capacity of a bridge shall be determined by the computation of stresses based on authentic records of the design, details, materials, workmanship, and physical condition, including data obtained by inspection (and tests if the records are not complete). For a specific service the location and behavior under load shall be taken into account.

Inspection

2. An inspection of the bridge shall be made to determine:

(a) Whether the actual sections and details conform to the drawings.
(b) Any additions to the dead load not shown on the plan, such as heavier deck or rail, walks, pipe lines, conduits, signal devices, and wire supports.
(c) The position of the track with respect to the center line of the bridge.
(d) Any loss of metal due to corrosion and wear. This determination should be made by caliper measurements after removal of scale.
(e) The physical condition, noting such defects as unequal stress in tension members, loose rivets, worn pins, crooked or damaged members, and cracked parts; also the condition of braces intended to limit the slenderness ratio of columns or compression flanges.
(f) The condition of pin plates of tension members, especially those inside other members.
(g) The condition of slender tension members, such as eye-bars, with special reference to the effects of vibration of the member caused by passing trains or by wind.
(h) The condition of floor beams and their connections to truss members, particularly where the connection has been shaped to clear eye-bar heads or the bottom chord.
(i) The condition of stringer connections, especially for shallow stringers.

Computation of Stresses

3. The computation of stresses shall be made for the details as well as for the main members, giving particular attention to:

(a) The increased load carried by any truss, girder, or floor member due to the eccentricity of the load. This applies to bridges on tangent where the tracks are off center as well as to bridges on curves.

(b) Spacing of web stiffeners, lacing and forked ends of compression members, eccentricity of riveted joints and connections, unequal stress in tension members, and secondary stresses.

(c) Pin plates of tension members. The following rules are given as a guide, when the body of the member is carrying the limiting stress:

1. The net section through the pin hole transverse to the axis of the member should be 40 per cent. greater than the net section of the member.
2. The net section beyond the pin hole on any line parallel to the axis of the member should be not less than three-fourths of the net section of the member.

Loads and Forces

4. Bridges shall be computed for the following loads and forces:

Dead load
Live load
Impact
Centrifugal force
Other lateral forces
Longitudinal force

Dead Load

5. The dead load shall be the weight of the bridge including the deck and track, together with that of any other fixed loads.

Live Load

6. The live load shall be one of the Cooper's E series or else a load consisting of a specific locomotive or other equipment, depending on the purpose for which the rating is desired.

If the live load is to be a specific locomotive and cars (or other equipment) complete data shall be obtained, including the spacing of the axles and the static load on each axle. If the precise method of determining impact is to be used, the data shall include the counterbalance report of the locomotive.

Impact

7. To the computed static live load stresses there shall be added the impact produced by the live load in motion. Impact need not be added to the lateral forces.

8. The impact ordinarily to be provided for shall be determined by the rules for impact in the AREA Specifications for Steel Railway Bridges.

Precise Determination of Impact

9. A more precise determination of the impact produced by a specific locomotive may be made by computing separately the following effects:

(a) Track Joint Effect
(b) Lurching Effect
(c) Hammer Blow Effect

The total impact shall be the sum of these three effects, computed as follows, but not less than 15 per cent of the static live load.

(a) Track Joint Effect

The track joint effect shall be taken as that produced by a concentrated load, acting on each rail at the center of the span, equal to:

$$\frac{W S^2}{20000}$$

in which

W = the maximum wheel load, in pounds.
S = the speed in miles per hour, but not greater than the synchronous speed.

(b) Lurching Effect

The lurching effect is the increase of load on one rail with a corresponding decrease on the other. It shall be taken as 20 per cent of the static live load and be distributed to the supporting members.

(c) Hammer Blow Effect

The hammer blow effect is the centrifugal force due to the revolving over-balance on the locomotive drivers. It is determined as follows:

1. For spans the loaded frequency of which is so high that synchronous speeds cannot be attained, the dynamic magnification is unity and, at any speed N
$$H = 100\,\beta\,N^2$$
2. For spans from 35 to 90 feet in length the loaded frequency of which is such that synchronous and higher speeds may be attained, at synchronous speed
$$H = 100\,\frac{\beta n}{2p}\left(1.65 - \frac{(L-63)^2}{1200}\right)$$
3. For spans of other lengths the loaded frequency of which is such that synchronous speeds may be attained, at synchronous speed
$$H = 100\,\frac{\beta n}{2p}$$
4. For all spans on which synchronous speeds may be attained, at speeds other than the synchronous speed
$$H = \frac{100\,\beta N^2}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(2pn\,\frac{N}{n}\right)^2}}$$

In the foregoing expressions for hammer blow effect:

H = hammer blow effect, in percentage of the static live load.
L = length of span, in feet.
d = central deflection of the span, in inches, due to the dead load.
D = central deflection of the span, in inches, due to the static live load when placed in the position for maximum moment.
D_h = central deflection of the span, in inches, due to the hammer blow of the locomotive drivers, at 1 r.p.s., acting statically at the center.

The total hammer blow of the locomotive is 1.414 times the hammer blow on one side as given by the counterbalance report.

N = number of revolutions per second of the locomotive drivers.
$n = \sqrt{\frac{12}{d+D}}$ = the frequency of the span, vibrations per second, under the load being considered.

Synchronous speed is the speed at which N is equal to n.

$\beta = \frac{D_h}{D}$ = ratio of the deflection due to the hammer blow at 1 r.p.s. to the static live load deflection.
p = the damping constant of the span which may be expressed as follows:

For girder spans, $p = \frac{3.2}{L+32}$

For truss spans, $p = \frac{14}{L+350}$

For the trusses or girders of through spans, all stringers, and the girders of deck spans (if the stringers or the girders of deck spans are so braced that they act in unison) one-half of the total hammer blow of the locomotive shall be assumed as acting on each stringer, girder, or truss.

If the stringers or girders are directly under the rail and are so inadequately braced that they oscillate independently of one another, the hammer blow from one side of the locomotive shall be assumed as acting on each stringer or girder.

The hammer blow effect, computed as above for bending, shall be used for shear, and is applicable only to steel spans simply supported.

Centrifugal Force

10. On curves, the centrifugal force, based on the actual speed of operation, and assumed to act 6 feet above the rail, shall be taken as a percentage of the static live load equal to:

$$0.00117S^2D$$

in which

$S =$ speed in miles per hour.
$D =$ degree of curve.

Wind

11. The wind force shall be considered as a moving load, acting in any horizontal direction. The wind force on the bridge shall be taken at 30 pounds a square foot of:

(a) One and one-half times the vertical projection of the floor system and girders.
(b) The vertical projection of all trusses.

but not less than 200 pounds a linear foot of loaded chord or flange, and 150 pounds a linear foot of unloaded chord or flange.

(c) The vertical projection of columns and tower bracing.

The wind force on the train shall be taken as 300 pounds a linear foot on one track, applied eight feet above the top of the rail.

Sway of Locomotives

12. The lateral force to provide for the effect of the sway of locomotives (in addition to the other lateral forces), shall be a moving concentrated load equal to one-sixteenth of the weight of one locomotive without tender, applied at the top of the rail in either lateral direction at any point of the span.

Lateral Force Due to Impact

12a. The lateral component due to impact shall be taken as 5 per cent. of the total impact.

Longitudinal Force

13. The longitudinal force resulting from the starting and stopping of trains shall be the larger of:

(a) Force due to braking.
  Fifteen per cent of the static live load.
(b) Force due to traction.
  Twenty-five per cent of the total weight on the driving wheels, without impact.

The longitudinal force shall be taken on one track only and shall be assumed to act 6 feet above the top of the rail.

For bridges where, by reason of continuity of members or frictional resistance, much of the longitudinal force will be carried directly to the abutments (such as ballasted deck bridges of only three or four spans), only one-half of the longitudinal force shall be considered effective.

Live Load and Impact on Multiple Track Bridges

14. The application of the live load and the impact to multiple track bridges shall be as specified in the AREA Specifications for Steel Railway Bridges.

Permissible Stresses

15. The permissible unit stresses resulting from the loads and forces described in the preceding articles are the following, in which

$Y.P.$ = yield point of the material:

	Pounds per Square Inch	
	Open-Hearth Steel	*Wrought Iron and Bessemer Steel*
Axial tension, net section	0.80 $Y.P.$	0.80 $Y.P.$
Tension in extreme fibers of rolled shapes, girders, and built sections, net section ..	0.80 $Y.P.$	0.80 $Y.P.$
Axial compression, gross section: (For columns centrally loaded and with values of $\frac{l}{r}$ not greater than 140)		
Riveted ends	$\frac{0.80\ Y.P.}{18000}\left(15000 - \frac{1}{4}\frac{l^2}{r^2}\right)$	$\frac{0.80\ Y.P.}{15000}\left(12500 - 0.21\frac{l^2}{r^2}\right)$
Pin ends	$\frac{0.80\ Y.P.}{18000}\left(15000 - \frac{1}{3}\frac{l^2}{r^2}\right)$	$\frac{0.80\ Y.P.}{15000}\left(12500 - 0.28\frac{l^2}{r^2}\right)$
l = length of member in inches. r = least radius of gyration of the member in inches.		
For columns with values of $\frac{l}{r}$ greater than 140 and for columns of known eccentricity, see Appendix on Column Formulas of the AREA Specifications for Steel Railway Bridges, using appropriate values for y, f, and E.		
Compression in extreme fibers of rolled shapes, girders, and built sections, subject to bending, gross section ...	$\frac{0.80\ Y.P.}{18000}\left(18000 - 5\frac{l^2}{b^2}\right)$	$\frac{0.80\ Y.P.}{15000}\left(15000 - 4\frac{l^2}{b^2}\right)$
l = length, in inches, of the unsupported flange between lateral connections or knee braces. b = flange width, in inches.		
Tension in extreme fibers of pins, assuming loads concentrated at centers of bearings	1.67 $Y.P.$	1.67 $Y.P.$

	Pounds per Square Inch	
	Open-Hearth Steel	*Wrought Iron and Bessemer Steel*
If the members are packed close together on the pin, the bending stress may be disregarded unless the tension in the extreme fiber exceeds 60,000 for open-hearth steel, or 50,000 for wrought iron and Bessemer steel.		
Shear in plate girder webs and rolled beams, gross section ..	0.60 *Y.P.*	0.60 *Y.P.*
Shear in rivets and pins	0.73 *Y.P.*	0.73 *Y.P.*
The permissible values for shear shall be reduced 20 per cent for countersunk rivets, floor connection rivets, and turned bolts.		
Bearing on rivets, pins, outstanding legs of stiffener angles, and other steel parts in contact, may be disregarded unless there is visible deformation of the parts in contact.		

In the absence of definite records of tests, the yield point shall be taken as 30,000 for open-hearth steel and 25,000 for wrought iron and Bessemer steel.

Stresses in plate girders may be computed either by the moment of inertia of their net sections or by assuming that the flanges are concentrated at their centers of gravity. In the latter case, one eighth of the gross section of the web, if continuous or properly spliced, may be considered as flange section. Girders having unusual sections shall be computed by the moment-of-inertia method.

Conclusions

16. If the stresses exceed those permissible under these rules, the speed shall be so restricted, if practicable, that the permissible stresses will not be exceeded. If the speed cannot be so restricted, or if the design or the physical condition of the bridge makes it necessary, it shall be strengthened or renewed. When the permissible stresses are closely approached, or when the physical condition of the main members or the details is not good, the bridge shall be kept under close inspection as long as it is continued in service.

REPORT OF SPECIAL COMMITTEE ON LIVE LOAD AND IMPACT

O. F. Dalstrom, *Chairman;* S. F. Grear, *Vice-Chairman;* A. N. Laird, *Vice-Chairman;*
G. M. Cornell, J. B. Hunley, P. G. Lang, Jr.
Theo. Doll, C. S. Johnson, C. P. Schantz,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Live Load (Appendix A).

(2) Impact. Progress in study (Appendix B).

Appendix A

LIVE LOAD

Your Committee recommends for the live load to be used in designing structures carrying track, Cooper's E–72 load as shown in Fig. 1 and Fig. 2.

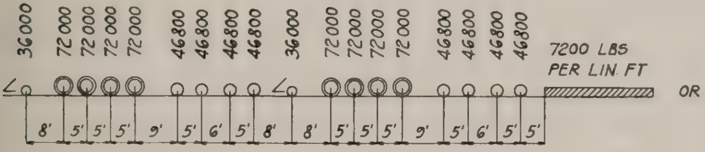

FIG. 1

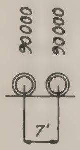

FIG. 2

Where a different live load is desired, the Engineer shall specify the load to be used; such load shall be proportional to the recommended load, with the same axle spacing.

Appendix B

IMPACT

While your Committee is not prepared to submit any recommendations on impact for your consideration at this time, your attention is invited to the record of tests and discussion of "Impact in Steel Railway Bridges of Simple Span", in AREA Bulletin No. 380, October, 1935, by J. B. Hunley, a member of this Committee.

In the Foreword to this discussion is given a brief review of the pioneer work in this field by Prof. F. E. Turneaure, Dean of the College of Engineering, University of Wisconsin, the results of which were published in the AREA Proceedings of 1911. Following this review of Dean Turneaure's work is given a summary of the research work carried out in foreign countries. The author then presents the report of his tests on steel bridges of the C.C.C.&St.L. Railroad during the years 1931 to 1934 inclusive. This

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Bulletin 382, December, 1935.

report is based on about 2100 test records on 39 bridges, all simple spans and most of them open-deck bridges. This is the most comprehensive report that has been made on the subject of impact. While it served the immediate purpose that the C.C.C.&St.L. Railroad had in view and was the basis of the present AREA impact formula for steel railway bridges, it also indicates the need of extending this research to cover spans of lengths and types different from those tested, particularly short spans, steel spans with decks carrying ballasted tracks, continuous or rigid frame structures, and concrete bridges of all types.

Special Committee on Live Load and Impact,
O. F. Dalstrom, *Chairman.*

REPORT OF COMMITTEE VI—BUILDINGS

G. A. Rodman, *Chairman;*
G. A. Belden,
G. H. Burnette,
Eli Christiansen,
A. C. Copland,
W. T. Dorrance,
E. A. Dougherty,
Hugo Filippi,
J. N. Grim,
E. A. Harrison,
A. T. Hawk,
C. D. Horton,
Neal D. Howard,
A. C. Irwin,
F. R. Judd,
E. K. Mentzer,
O. G. Wilbur, *Vice-Chairman;*
A. H. Morrill,
C. H. Sandberg,
A. L. Sparks,
A. B. Stone,
A. T. Upson,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents its report herewith on the following subjects:

(1) Revision of Manual (Appendix A). It is recommended that the material contained herein be adopted for publication in the Manual.

(2) Preparation of specifications for railway buildings (Appendix B). It is recommended that the specifications in this report be adopted for publication in the Manual.

(3) Influence of the design of buildings on fire insurance rates. Progress in study —no report.

(4) Determination of the destructible value of structures which can be collected in case of fire (Appendix C). Progress report.

(5) Different types of paint and their economical selection, collaborating with Committee XV—Iron and Steel Structures. Progress in study—no report.

(6) Application of stainless and rust-resisting metals to building construction (Appendix D). Final report.

(7) Type of foundation best suited for railway buildings. Progress in study—no report.

(8) Mill type and other heavy wood construction for railway buildings. Report submitted in 1935 as information and discussion invited. Recommended subject be discontinued.

(9) Design of small cold storage plants for railway use. Progress in study—no report.

The Committee on Buildings,
G. A. Rodman, *Chairman.*

Bulletin 382, December, 1935.

Appendix A

(1) REVISION OF MANUAL

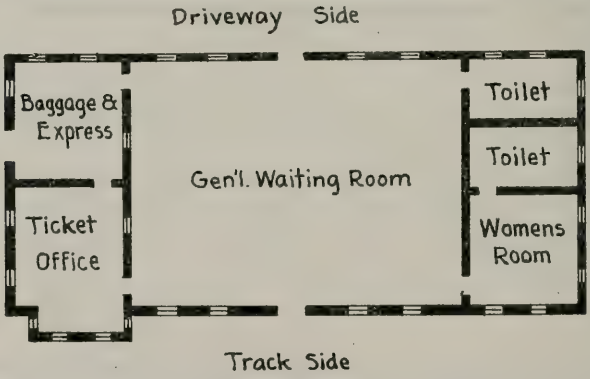
O. G. Wilbur, Chairman, Sub-Committee; G. A. Belden, W. T. Dorrance, F. R. Judd.

The Committee recommends the following revisions be made in the Manual. Attention is directed to the fact that this Committee collaborated with Committee XXIII—Shops and Locomotive Terminals, in revising and combining the text pertaining to Oil Houses and Paint Stores. Recommendation covering the revised text is included in the report of Committee XXIII.

PASSENGER STATIONS

Page 264, 1929 Manual.—Amend to read: "(2) It permits proper development of a retiring room for women, with a private entrance to the lavatory in stations at junction points where there may be long layovers."

Page 264, 1929 Manual.—Substitute the following sketch for the one in the Manual:



Division of Floor Area Recommended for Passenger Stations With One General Waiting Room

STAIRWAYS AND RAMPS

Page 266, 1929 Manual.—Substitute for corresponding matter in 2nd paragraph: "Passenger ramps with surface treated with non-slip material are in successful use on grades up to twelve per cent, but where conditions permit, grades of ten per cent or less are recommended."

SCALES

Page 271, 1929 Manual.—Substitute for corresponding matter, (a) General, "Scales are a necessary part of the freight house equipment."

OIL HOUSES

Pages 274–275, 1929 Manual.—Eliminate material under this caption.

REST HOUSES

Page 275, 1929 Manual.—Change the word "trainmen" in the first sentence to "employees".

Omit the second sentence, "The need of these houses is increasing with the construction of large terminals away from the centers of the town".

SECTION TOOL HOUSES

Pages 277–278, 1929 Manual.—Change the word "handcar" appearing in Class A and Class B to "motorcar".

SPECIFICATIONS FOR BUILDINGS FOR RAILWAY PURPOSES

Page 288, 1929 Manual.—Insert following immediately preceding "Section 1":

Specifications for Buildings for Railway Purposes

Index

Architectural Terra Cotta	Section	8
Brickwork	"	5
Carpentry	"	13
Chimneys	"	30–A–B–C–D–E
Concrete Architectural Stone	"	9
Drainage	"	3
Elevators, Hydraulic, Baggage and Freight	"	28
Excavation, Filling and Backfilling	"	2
Floors:		
Asphalt Block	"	25–B
Asphalt Mastic	"	24–B
Brick	"	21
Cement Grouted	"	26–C
Wood Block	"	23–B
General Conditions	"	1
Glazing	"	16
Hardware	"	17
Heating	"	19
Lathing	"	14
Marble and Tile Work	"	15
Metal Work, Ornamental and Miscellaneous	"	12–B
Millwork	"	13
Painting	"	16
Pavements:		
Asphalt Block	"	25–A
Asphalt Macadam	"	26–B
Brick	"	21
Cement Grouted	"	26–C
Concrete	"	22
Macadam	"	26–A
Sheet Asphalt	"	24–A
Wood Block, Creosoted	"	23–A
Plastering	"	14
Platforms, Cement Grouted	"	26–C
Plumbing	"	18
Roofing:		
Built-up Roofing Materials	"	10–D
Clay Roofing Tile	"	10–B
Concrete Roofing Tile	"	10–A
Slate	"	10–C
Screens	"	31–A–B
Sewers and Drainage	"	3
Sheet Metal Work	"	11
Sprinkler System	"	27
Stone Masonry and Cut Stone Work	"	6
Structural Steel and Iron	"	12–A
Tile, Clay Hollow	"	7
Tile Work and Marble	"	15
Wiring, Electric Light	"	20

Section 3

SEWERS AND DRAINAGE

Page 296, 1929 Manual.—Substitute the following:

“8. Mortar: (For pipe joints)

“All mortar shall be composed of one part Portland cement and three parts sand.”

“9. Cement and Sand

“(a) Cement:

“The cement shall meet the requirements of the American Railway Engineering Association for Portland cement.

“(b) Sand:

“Sand used for mortar shall be clean, washed, hard and well graded and shall not contain more than 3 per cent by weight of such organic impurities as loam, clay, mica, etc., determined by decantation, and shall be tested for such impurities in accordance with the current Standard Methods of Tests of the ASTM, Serial designation C–40 and D–136.

“Mortar sand shall be free from salt, alkalies and other deleterious substances.”

Section 5

BRICKWORK

Pages 299–300, 1929 Manual.—Substitute the following:

“8. Sand

“Sand used for mortar shall be clean, washed, hard and well graded and shall not contain more than 3 per cent by weight of such organic impurities as loam, clay, mica, etc., determined by decantation, and shall be tested for such impurities in accordance with the current Standard Methods of Tests of the ASTM, Serial designation C–40 and D–136.

Mortar sand shall be free from salt, alkalies and other deleterious substance.

“The sand shall have a fineness modulus ranging between 2.00 and 2.50. In general a sieve analysis shall show the sand to come within the following limits:

Passing a No. 8 sieve	100 per cent
“ “ No. 50 “	30 per cent
“ “ No. 100 “ not over	10 per cent

“Where so required for face brickwork, sand shall be white, but otherwise conform to this specification.”

“9. Lime

“Lime shall conform to the Specifications for Quicklime for Structural Purposes of the ASTM, Serial designation C–5. If the use of hydrated lime is authorized by the Engineer, it shall conform to the Specifications for Hydrated Lime for Structural Purposes of the ASTM, Serial Designation C–8.”

“11. Mortar

“For all common brick the mortar shall be composed of one part Portland cement, 3½ parts sand and ½ part lime putty, measured by volume.

“For pressed brick where the mortar is not to be colored, the mortar shall be composed of one part Portland cement, 3 parts sand, and 1 part lime putty by volume. Where colored mortar is to be used, the lime putty content shall be reduced to ½ part.”

Section 6

STONE MASONRY AND CUT STONE WORK

Pages 303–304, 1929 Manual.—Substitute the following:

“7. Cement, Sand, Lime, Mortar

“(a) Cement

“The cement shall meet the requirements of the American Railway Engineering Association for Portland cement.

“(b) Sand

“All sand used for mortar shall be clean, washed, hard and well graded and shall not contain more than 3 per cent by weight of such organic impurities as loam, clay, mica, etc. determined by decantation, and shall be tested for such impurities in accordance with the current Standard Methods of Tests of the ASTM, Serial Designations C–40 and D–136.

"Mortar sand shall be free from salt, alkalies and other deleterious substances.

"The sand shall have a fineness modulus ranging between 2.00 and 2.50. In general a sieve analysis shall show the sand to come within the following limits:

Passing a No. 8 sieve		100 per cent
" " No. 50 "		30 per cent
" " No. 100 "	not over	10 per cent

"(c) Lime

"Lime shall conform to the Specifications for Quicklime for Structural Purposes of the ASTM, Serial Designation C–5. If the use of hydrated lime is authorized by the Engineer, it shall conform to the Specifications for Hydrated Lime for Structural Purposes of the ASTM, Serial Designation C–6.

"(d) Mortar

"For stone masonry where the mortar is not to be colored, the mortar shall be composed of one part Portland cement, 3 parts sand and 1 part lime putty by volume. Where colored mortar is to be used, the lime content shall be reduced to ½ part."

Section 7

CLAY HOLLOW TILE

Page 306, 1929 Manual.—Substitute the following:

"4. Cement, Sand, Lime, Mortar

"(a) Cement

"The cement shall meet the requirements of the American Railway Engineering Association for Portland cement.

"(b) Sand

"All sand used for mortar shall be clean, washed, hard and well graded and shall not contain more than 3 per cent by weight of such organic impurities as loam, clay, mica, etc. determined by decantation, and shall be tested for such impurities in accordance with the current Standard Methods of Tests of the ASTM, Serial designation C–40 and D–136.

"Mortar sand shall be free from salt, alkalies and other deleterious substances.

"The sand shall have a fineness modulus ranging between 2.00 and 2.50. In general a sieve analysis shall show the sand to come within the following limits:

Passing a No. 8 sieve		100 per cent
" " No. 50 "		30 per cent
" " No. 100 "	not over	10 per cent

"(c) Lime

"Lime shall conform to the Specifications for Quicklime for Structural Purposes of the ASTM, Serial Designation C–5. If the use of hydrated lime is authorized by the Engineer, it shall conform to the Specifications for Hydrated Lime for Structural Purposes of the ASTM, Serial Designation C–6.

"(d) Mortar

"For load bearing tile the mortar shall be composed of one part Portland cement, 3 parts sand and ¼ part lime putty by volume.

"For non-load bearing tile, the mortar shall be composed of one part Portland cement, 5 parts sand and 1 part lime putty by volume."

Section 8

ARCHITECTURAL TERRA COTTA

Page 309, 1929 Manual.—Substitute the following:

"7. Cement, Sand, Lime, Mortar

"(a) Cement

"The cement shall meet the requirements of the American Railway Engineering Association for Portland cement.

"(b) Sand

"All sand used for mortar shall be clean, washed, hard and well graded and shall contain not more than 3 per cent by weight of such organic impurities as loam, clay, mica, etc., determined by decantation, and shall be tested in accordance with the current Standard Methods of Tests of the ASTM, Serial Designations C–40 and D–136.

"Mortar sand shall be free from salt, alkalies and other deleterious substances.

"The sand shall have a fineness modulus ranging between 2.00 and 2.50. In general a sieve analysis shall show the sand to come within the following limits:

Passing a No. 8 sieve	100 per cent
" " No. 50 "	30 per cent
" " No. 100 " not over	10 per cent

"(c) Lime

"Lime shall conform to the Specifications for Quicklime for Structural Purposes of the ASTM, Serial Designation C–5. If the use of hydrated lime is authorized by the Engineer, it shall conform to the Specifications for Hydrated Lime for Structural Purposes of the ASTM, Serial Designation C–6.

"(d) Mortar

"Mortar for architectural terra cotta shall be composed of one part Portland cement, 3½ parts sand and ½ part lime putty by volume."

Section 9

CONCRETE ARCHITECTURAL STONE

Page 312, 1929 Manual.—Substitute the following:

"7. Cement, Sand, Lime, Mortar

"(a) Cement

"The cement shall meet the requirements of the American Railway Engineering Association for Portland cement.

"(b) Sand

"All sand used for mortar shall be clean, washed, hard and well graded and shall contain not more than 3 per cent by weight of such organic impurities as loam, clay, mica, etc., determined by decantation, and shall be tested for such impurities in accordance with the current Standard Methods of Tests of the ASTM, Serial Designations C–40 and D–136.

"Mortar sand shall be free from salt, alkalies and other deleterious substances.

"The sand shall have a fineness modulus ranging between 2.00 and 2.50. In general a sieve analysis shall show the sand to come within the following limits:

Passing a No. 8 sieve	100 per cent
" " No. 50 "	30 per cent
" " No. 100 " not over	10 per cent

"(c) Lime

"Lime shall conform to the Specifications for Quicklime for Structural Purposes of the ASTM, Serial Designation C–5. If the use of hydrated lime is authorized by the Engineer, it shall conform to the Specifications for Hydrated Lime for Structural Purposes of the ASTM, Serial Designation C–6.

"(d) Mortar

"Mortar for concrete architectural stone shall be composed of one part Portland cement, 3½ parts sand and ½ part lime putty by volume."

Section 30–B

BRICK CHIMNEYS

Page 28, Bulletin No. 356.—Substitute the following:

"7. Concrete

"Concrete for foundations shall conform with the American Railway Engineering Association Specifications for 2000 pound concrete."

"9. Cement, Sand, Lime, Mortar

"(a) Cement

"The cement for mortar shall meet the requirements of the American Railway Engineering Association for Portland cement.

"(b) Sand

"All sand used for mortar shall be clean, washed, hard and well graded and shall contain not more than 3 per cent by weight of such organic impurities as loam, clay, mica, etc., determined by decantation, and shall be tested for such impurities in accordance with the current Standard Methods of Tests of the ASTM, Serial Designations C–40 and D–136.

"Mortar sand shall be free from salt, alkalies and other deleterious substances.

"The sand shall have a fineness modulus ranging between 2.00 and 2.50. In general a sieve analysis shall show the sand to come within the following limits:

Passing a No. 8 sieve	100 per cent
" " No. 50 "	30 per cent
" " No. 100 " not over	10 per cent

"(c) Lime

"Lime shall conform to the Specifications for Quicklime for Structural Purposes of the ASTM, Serial Designation C–5. If the use of hydrated lime is authorized by the Engineer, it shall conform to the Specifications for Hydrated Lime for Structural Purposes of the ASTM, Serial Designation C–6.

"(d) Mortar

"Mortar for the shaft of the chimney shall be composed of one part Portland cement, 5 parts sand and 2 parts lime putty by volume.

"Mortar for the lining shall be refractory mortar."

Section 18

PLUMBING

Page 376, 1929 Manual.—Substitute the following:

"8. Fixtures

"The Contractor shall furnish and install complete, in proper working order, all fixtures, locations of which are shown on the drawings. Fixtures shall be as manufactured by .... or approved equal."

Pages 381–401, 1929 Manual.—Omit all sketches covering plumbing fixtures, pp. 381 to 401, 1929 Manual.

Appendix B

(2) PREPARATION OF SPECIFICATIONS FOR RAILWAY BUILDINGS

F. R. Judd, Chairman, Sub-Committee; H. Filippi, A. C. Irwin, C. H. Sandberg, A. T. Upson.

The Committee submits for publication in the Manual the following specifications, previously published as part of Appendix B, pages 584 to 588, both inclusive, also pages 594 and 595, of Bulletin 373, Volume 36, Proceedings 1935:

Section 30–F. Genuine Wrought Iron Chimneys—Welded.

Section 10–D. Built-up Roofing, Type D–1. Asphalt Rag Felt and Asphalt (Smooth Surface) over Wood or Pre-cast Units. Built-up Roofing, Type D–2. Asphalt Rag Felt and Asphalt (Smooth Surface) over Homogeneous Roofs Cast in Place.

The following specification is submitted at this time for publication in the Proceedings as information for criticism:

Section 26–C. Cement Grouted Macadam Pavements, Floors and Platforms.

The Committee has received some comments on Specification 30–G, Reinforced Brick Masonry Chimneys, previously published as information last year. In order to benefit by further comments, it has been decided to hold this specification in abeyance for the time being, with the idea of probably presenting it for publication in the Manual at the next Convention.

Section 26–C

CEMENT GROUTED MACADAM PAVEMENTS, FLOORS AND PLATFORMS

1. General

The Contractor shall furnish all labor, materials, tools and equipment, except as otherwise noted or specified, which are necessary to complete entirely the cement grouted pavements, floors and platforms as herein specified, and as shown or implied on the drawings.

2. Description

Cement bound macadam pavement shall consist of a coarse aggregate bound together by Portland cement grout. It shall be constructed by placing on a prepared subgrade a layer of coarse aggregate over which is poured a grout of such fluidity that it immediately flows through and completely fills the voids in the coarse aggregate.

3. Scope

These specifications apply to pavements and floors supported directly on the ground, such as platforms at railway stations, walks, floors in shops and roadway buildings, runways and driveways in shop yards, and similar facilities.

4. Materials

Portland cement, fine and coarse aggregate and water shall comply with Section 4—Standard Specifications for Concrete Work, except as hereinafter provided.

Crushed stone, gravel or slag conforming to the requirements for first-class ballast as to hardness and durability may be used subject to approval of the Engineer.

Fine aggregate shall be a natural sand.

5. Gradation of Aggregates

Coarse aggregate shall not contain more than 5 per cent of material passing the ¾-inch sieve, nor more than 10 per cent retained on the 3½-inch sieve. The allowable range between the maximum and minimum size of any aggregate used shall not exceed 1½ inches.

The gradation of the fine and coarse aggregate shall preferably fall within the limits set by the following table:

	Coarse Aggregate	*Accompanying Fine Aggregates*
1	Passing 2" sieve, 90–100 per cent Passing 1" sieve, 0–15 per cent	Passing No. 8 sieve, 95–100 per cent Passing No. 50 sieve, 10–30 per cent Passing No. 100 sieve, 0–5 per cent (Approximately 7¼ gallons of water per sack of cement)
2	Passing 2½" sieve, 90–100 per cent Passing 1½" sieve, 0–15 per cent	
3	Passing 1½" sieve, 90–100 per cent Passing ¾" sieve, 0–5 per cent	Passing No. 8 sieve, 100 per cent Passing No. 14 sieve, 90–100 per cent Passing No. 50 sieve, 15–30 per cent Passing No. 100 sieve, 0–10 per cent (Approximately 7¾ gallons of water per sack of cement)
4	Passing 3" sieve, 90–100 per cent Passing 2" sieve, 0–15 per cent	Passing No. 4 sieve, 95–100 per cent Passing No. 14 sieve, 60–80 per cent Passing No. 50 sieve, 10–30 per cent Passing No. 100 sieve, 0–5 per cent (Approximately 6¾ gallons of water per sack of cement) or either of above
5	Passing 3½" sieve, 90–100 per cent Passing 2½" sieve, 0–15 per cent	

Note.—The first two gradings are preferred. Quantities of water are given as a guide, and the amounts required may vary considerably from those suggested, depending on sand grading.

6. Subgrade

The surface of the subgrade shall be uniform, well compacted and free from loose material. Any material causing soft or spongy places in the subgrade shall be replaced with suitable material and compacted, before any of the coarse aggregate is spread thereon.

The subgrade shall be drained where frost heaving may be expected.

7. Forms

Side forms shall have a height equal to the edge thickness of the finished work and be strong enough to withstand subsequent construction operations. They shall be firmly staked in place and shall not be removed until 12 hours after the work is finished. If the aggregate is compacted by a roller, the forms shall be more substantial than if it is compacted by hand or by vibration.

8. Joints

Where specified by the Engineer, joints shall be formed by installing a wooden or metal bulkhead on the subgrade prior to the spreading of coarse aggregate, or by trenching the coarse aggregate. These bulkheads shall be set ½ inch below top of finished surface and shall be firmly fastened in place so that they will not be disturbed by subsequent construction operations. Preformed joint filler used in connection with heavy rolling shall be supported by substantial metal bulkhead which shall be removed prior to final finishing. If compaction and finishing is done by vibration or hand tamping and finishing, properly supported preformed joint filler may be used independently. The edges at all joints shall be rounded, the joint cleaned out and the pavement made level at the joint by filling with approved bituminous material (Fig. 1). All joints shall be vertical and full depth of pavement, floor or platform.

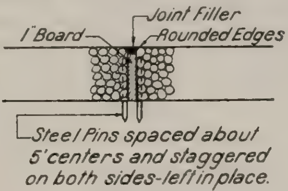

Joint Filler
1" Board
Rounded Edges
Steel Pins spaced about 5' centers and staggered on both sides-left in place.

FIG. 1.—Trenched Bulkhead Joint.

9. Placing Coarse Aggregate

The coarse aggregate shall be handled so as to prevent segregation of sizes and inclusion of dirt or other foreign material. It shall be spread evenly on the prepared subgrade to a depth which will give, after compaction and final finishing, a pavement of the thickness and crown specified. (See Addenda (1)).

There shall be no unnecessary trucking or hauling over the coarse aggregate after spreading.

10. Compaction

The coarse aggregate shall be compacted by not less than two complete rollings or by tamping and/or vibration as suitable for each kind of aggregate and as specified by the Engineer. The roller shall weigh not less than 3 nor more than 6 tons and the rollers shall be tandem. Rolling shall progress by ½ laps from sides toward center lines. After compaction the surface shall be corrected by removal or addition of coarse aggregate.

11. Grout

The grout shall be in the proportions of 1 bag (94 pounds) of cement to approximately 2 cu. ft. of moist sand (approximately 190 lb.) and sufficient mixing water to produce only sufficient fluidity to flow to the bottom of the aggregate and fill the voids completely. If high early strength grout is used, the proportions shall be 1 bag of cement to approximately 150 lb. of sand, or high early strength cement may be used in the proportions of 1 bag of cement to 190 lb. of sand.

The amount of mixing water per sack of cement to produce proper fluidity shall be determined by trial, and frequent fluidity tests shall be made during grouting operations, the mixing water being regulated to secure penetration as follows: Test holes shall be dug to the subgrade in the coarse aggregate at some distance ahead of grouting. These test holes shall be observed as grouting operations proceed. When the grout on the surface of the aggregate is one foot or more away, unsegregated grout shall enter the bottom of the test holes. When grout does not so enter the bottom of the test hole, grouting operations shall cease until proper adjustments are made to insure satisfactory penetration. A large amount of free water (not grout) coming to the surface or flowing ahead on the subgrade will be evidence that too much mixing water is being used.

12. Mixing Grout

The cement grout mixer shall be of a type approved by the Engineer and the mixing time shall be not less than one minute. A positive approved method shall be provided for measuring the amount of water for each batch. The grout may be mixed on the job, at a central plant with agitator delivery trucks or in a truck mixer.

The capacity of the mixer shall be ample to maintain the desired rate of progress. For small jobs the grout may be hand mixed in tight troughs or boxes or other convenient tight receptacles.

13. Distributing Grout

Regardless of the mixing method, the grout shall be deposited upon the coarse aggregate without segregation and in such a way that the coarse aggregate is not unduly disturbed.

Grout shall not be spilled on the ungrouted coarse aggregate except where grouting operations are in progress.

Where water is readily available, the coarse aggregate shall be lightly sprinkled with water before grouting if necessary to facilitate penetration. Only sufficient water shall be used to moisten the aggregate, and not flow onto the subgrade.

Grouting operations shall be continuous between joints or during each day's grouting operation. Grout distribution shall proceed continuously from side to side of the area and it shall be broomed ahead to prevent formation of air or water pockets in the aggregate already grouted. Sufficient grout shall be used to embed the coarse aggregate firmly after compaction and leave a thin film over the coarse aggregate.

14. Final Compaction

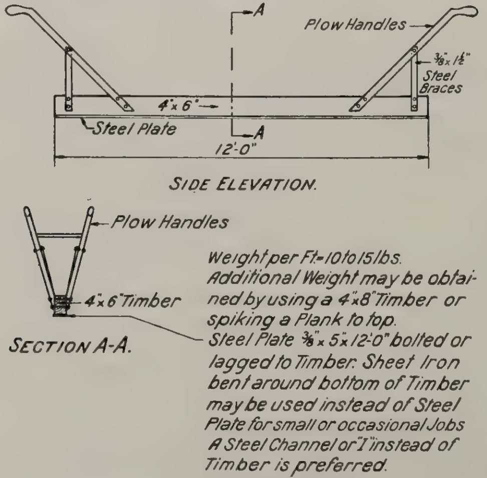
Final compaction shall be obtained by one or a combination of—

(a) Rolling
(b) Vibration
(c) Hand Tamping

(a) Rolling.—A tandem roller as specified in article 10 or by the Engineer shall be used. Final rolling shall begin within from 30 minutes to about one hour after grouting, depending on the weather and working conditions, and when free water is no longer released from the grout to the surface. The surface shall be rolled from 3 to 6 times, progressing from sides toward the center with ½ laps or until a hard, compact, even surface is obtained. The amount of grout on the surface shall be kept to a minimum required to cover the coarse aggregate. During rolling operations, hand squeegees or light push brooms shall be used to distribute the grout evenly over the surface, and to remove any excess grout. Grout may be added to the surface where necessary to embed the coarse aggregate properly.

Major irregularities in the surface shall be corrected with stone rakes by leveling high spots and filling low spots with ½ inch coarse aggregate. Additional grout shall be added if necessary. All places adjusted shall be recompacted.

(b) Vibration.—Vibration finishing equipment shall consist of a screed carrying one or more vibrating elements. The screed shall be given a "sawing" motion as it is



Weight per Ft.=10 to 15 lbs.
Additional Weight may be obtained by using a 4"x8" Timber or spiking a Plank to top.
Steel Plate 3/8"x 5"x 12'-0" bolted or lagged to Timber. Sheet Iron bent around bottom of Timber may be used instead of Steel Plate for small or occasional Jobs
A Steel Channel or "I" instead of Timber is preferred.

FIG. 2.—Hand Tamping Template.

passed over the surface. Hand squeegees or light push brooms shall be used to distribute the grout evenly and to remove any excess grout. Grout may be added to the surface to embed coarse aggregate and high or low spots corrected as specified under 14 (a).

(c) Hand Tamping.—Immediately after grouting, the surface shall be tamped with a longitudinal tamping template approximately 12 ft. long and weighing from 10 to 15 lb. per ft. (Fig. 2), to embed aggregate displaced during grouting, and to secure the utmost of compaction practicable. Tamping shall proceed across the pavement parallel to the center line. The template shall be lifted vertically from 6 to 10 inches and allowed to fall of its own weight, then moved transversely about one-half the width of the tamping face for the next stroke. The tamping shall proceed in this manner for the entire width of the pavement, after which the template shall be moved forward longitudinally about one-half of its length and tamping again proceed as above described. Tamping the second time, if needed, shall proceed in the same manner. Further compaction, after an interval of time, shall be required as specified under "Finishing". Paving tampers weighing 25 lb. may be used to correct high spots and consolidate additional aggregate placed at low spots.

15. Finishing

Finishing shall begin after an interval of from 30 minutes to one hour, depending on weather and working conditions, after compacting by rolling, or vibrating and/or tamping as above specified. Surface irregularities of more than ¼ inch measured from a ten-foot straight-edge or surface template shall be corrected either by the use of a hand tamper weighing not less than 25 pounds or by trimming such places with stone rakes and then recompacting with the longitudinal tamping template.

Additional grout shall be applied where necessary to correct the surface and excess grout shall be removed with squeegees or light push brooms during the tamping operations.

Immediately following this final tamping and correcting, the surface shall be smoothed by use of a long handled float 10 inches wide by 36 inches long with a handle sufficiently long to permit manipulation from either edge or side to 2 feet beyond the center.

After the surface has been smoothed, by the long handled float, excess water shall be removed and grout distributed by drawing a strip of wetted burlap across the surface. The burlap shall be about one foot longer than the surface and shall be drawn forward from the foremost corners, thus permitting the burlap to distribute itself over the surface. This operation shall be repeated if excess water rises to the surface.

After dragging with the burlap, the edges and joints shall be rounded with an edging tool having a ¾-inch radius. After disappearance of the water sheen, the surface shall be floated and broomed or, in the case of floors, troweled as specified by the Engineer.

16. Curing

The work shall be cured with wet burlap applied as soon as possible without marring the surface. It shall be kept wet for 48 hours. Other equivalent curing methods shall be subject to approval of the Engineer.

17. Opening to Traffic

Unless otherwise specified by the Engineer, the work may be opened to use after 7 days from the final finishing of the surface. If high early strength grout is used, the surface may be opened to use after 3 days from completion of finishing or as directed by the Engineer.

Addenda (1)

Approximate thickness of loose spread aggregate for a finished thickness, "t" on an untreated clay subgrade.

	Thickness of Loose Aggregate		
Compaction Method	*Crushed Stone*	*Slag*	*Gravel*
Power rolling	1.12t + .8″	1.09t + .6″	1.03t + .3″
Vibration and/or hand tamping	1.04t + .2″	1.08t + .2″	1.06t + .2″

The additional thickness of loose aggregate required to give a finished thickness, "t", depends upon the amount of compaction of the loose aggregate plus the loss of aggregate into the subgrade. Thus, the compaction of crushed stone by rolling with the specified roller is about 12 per cent. This is independent of the aggregate pushed into the subgrade. If the subgrade is hard, such as an old macadam base, or if it has been treated by rolling crushed stone or gravel into it, the subgrade loss will be zero and the compaction factor (term containing "t") only should be used. In general, gravel aggregate cannot be power rolled until after grouting.

Addenda (2)

Thickness of Cement Bound Macadam (Grouted Ballast) for Pavements and Floors

The required thickness of pavement and floor slabs depends upon the loads to be carried, the supporting power of the subgrade and the strength of concrete. A simple formula for thickness is:

$$d = \sqrt{\frac{3Wc}{\frac{M}{2}}}$$

where

d = uniform depth, in inches, of pavement slab or floor
W = wheel load in pounds
M = modulus of rupture of concrete, lb. per sq. in. (600 lb. per sq. in. for cement bound macadam, i.e., grouted ballast)
c = coefficient of subgrade support.

The factor $\frac{M}{2}$ represents the allowable working stress of the concrete. For general design purposes, it may be taken as ½ the modulus of rupture of the concrete since this will permit an unlimited number of loadings without fatigue of the concrete.

For general design purposes, where construction is on soil, a factor of 1.00 should be used for "*c*". Where construction is on thoroughly compacted cinders or ballast, a factor of .842 should be used for "*c*".

Thus, for cement bound macadam (grouted ballast) built on soil, the required thickness for an unlimited number of 2,000 pound wheel loads is

$$d = \sqrt{\frac{(3)\ (2{,}000)\ (1)}{300}} = 4.5''$$

If $W = 4{,}000$ lb.

$$d = \sqrt{\frac{(3)\ (4{,}000)\ (1)}{300}} = 6.3''$$

For the same loadings on compacted cinders or ballast with $c = .842$:

$W = 2{,}000$ lb.

$$d = \sqrt{\frac{(3)\ (2{,}000)\ (.842)}{300}} = 4.1''$$

$W = 4{,}000$ lb.

$$d = \sqrt{\frac{(3)\ (4{,}000)\ (.842)}{300}} = 5.8''$$

This indicates a required thickness of about 4½ inches of cement bound macadam (grouted ballast) for passenger platforms, truckways and shop floors, built on soil where loads will not exceed 2,000 lb. When built on compacted cinders or ballast, a 4-inch thickness will suffice.

Shop yard driveways of cement bound macadam (grouted ballast) built on soil to carry an unlimited number of motor trucks having 4,000 lb. wheel loads should have a uniform thickness of about 6½ inches. When built on compacted cinders or ballast, 6 inches will suffice. Pavements wider than 12 ft. shall have a longitudinal joint.

Appendix C

(4) DETERMINATION OF THE DESTRUCTIBLE VALUE OF STRUCTURES WHICH CAN BE COLLECTED IN CASE OF FIRE

A. C. Copland, Chairman, Sub-Committee; G. H. Burnette, Eli Christiansen, A. T. Hawk.

A report by this Committee on a related subject, "Study and report on what constitutes appraisal of fire losses", was published in Proceedings, Volume 31, pages 1225–1227. Recommendations in that report were developed from replies to a questionnaire. They outline the method of settlement in case of a partial or a total loss under the various insurance plans maintained by railroads. Included in the report is a list of the items of general expense, overhead, etc. which are likely to be overlooked in making an appraisal and adjustment of loss. Depreciation percentages for various types of buildings are given and the subject discussed generally.

The subject now under consideration is the determination of the amount which may be collected from an insurance company when an insured structure is damaged or destroyed by fire.

Conclusions

Fire insurance policies are contracts and while they contain similar stipulations these may be stated in different ways. They indemnify the insured against direct loss or damage by fire to the property covered. The amount which may be collected depends on the provisions of the insurance policy covering the structure. It is based on an accurate determination of the loss or damage to the insured, taking into consideration these provisions. It is therefore necessary to be familiar with the terms of the policy.

It is the obligation of the insured to see that the stipulations of the insurance contract or policy cover all the items which are legitimate claims in case of loss or damage.

The amount which can be claimed in case of a partial loss, that is when less than 50 per cent of the structure is damaged, is the cost, at current prices, to restore in kind the property destroyed. This shall include the cost of removing and disposing of the waste and damaged materials.

In the case of a total loss, the amount which can be claimed is the actual value of the property to the owner at the time of the loss or damage. This value is the cost to reproduce new, less depreciation, plus the cost of removing the debris, less the value of salvage.

The correct method of arriving at the reproduction cost is to prepare an itemized estimate of materials and labor, based on current local prices obtained from material dealers and contractors. This may be done by using the original plans and specifications or if these are not available, information will have to be supplied by persons familiar with the details of construction of the structure under consideration.

There should be included, in addition to the delivered and erected or installed cost, the following items when they are a part of the cost.

Architect's fees
Engineering and supervision
Interest during construction
Contractor's supervision
Contractor's overhead and profit
City permits
Public liability insurance premiums
Workmen's compensation
Fire insurance during construction
Owners risk and surety bonds

Incidental damage to foundations, sidewalks and parts other than the superstructure
Temporary protection
Temporary roof coverings
Protection of heating, plumbing and other apparatus against freezing
Clearing site of debris and all expense of whatever nature in connection therewith
Work done by the railway company's forces
Disposal of material at the dump
Switching charges
Transportation of men and materials

Estimating by the cubic foot, square foot or by means of rules, charts or tables should be avoided.

Depreciation should be determined on the basis of the actual physical condition of the several parts of the structure avoiding the use of arbitrary percentages and straight line methods.

The amount of depreciation for various types of buildings will depend on the care and maintenance and other physical conditions. Buildings in active use and normally maintained should have a destructible value of not less than 75 per cent of the reproduction cost.

Depreciation applies to the superstructure and equipment but not to the foundations except in special cases such as the substructure of piers, wharfs, etc.

Appendix D

(6) APPLICATION OF STAINLESS AND RUST-RESISTING METALS TO BUILDING CONSTRUCTION

E. A. Dougherty, Chairman, Sub-Committee; J. N. Grim, G. H. Burnette, E. A. Harrison, H. Filippi.

The tremendous development in building construction and design in recent years has resulted in a positive trend to a greater use of metals and metal alloys, not only structurally, but more particularly to their application in design, ornamentation and finish. Constant research work and study is being made by manufacturers to increase the use and application of these various metals and alloys. The greatest concentration is particularly centered around those metals and alloys which are considered non-staining and possess a high degree of resistance to oxidation or atmospheric corrosion.

Lead, zinc, nickel and copper are metallic elements which can be properly classed as rust-resisting for discussion in this report, together with alloys—brass, bronze, aluminum alloy, monel metal and stainless steel. The non-staining property of these metal and metal alloys are dependent upon whether used for interior or exterior finish, where in the case of exterior finish the action of the elements and impurities in the atmosphere tend to affect some of them so that possible staining of surrounding building surfaces is ever-present. Lacquering is used to overcome this staining. Metals such as chromium, nickel, zinc, gold and silver are employed extensively as a plating over other base metals which possess characteristics of staining and corrosion due to mere action of the weather and atmosphere. Gold and silver are used as plating mediums but their value limits their use to special classes of ornamentation and where cost is not limited. Economic conditions, low initial cost, maintenance and the requirements of design and ornamentation generally, govern the selection of metals for use in building construction.

The properties of metals or metal alloys must be sufficiently flexible to make them preferential to other materials and readily applicable to any characteristic use in building construction. The metal and alloys under discussion must be naturally limited to those which may be classified as non-corrodible. Generally speaking, the metals and alloys heretofore mentioned possess this property as well as others which are inherent in the materials themselves, but specifically—use, location and atmospheric and climatic conditions—may tend to nullify their non-staining properties.

Lead is noted for a great variety of use, industries fabricating materials for building construction finding it almost indispensible. On account of its remarkably high corrosion resistance, it is in great favor with construction for industries and manufacturing plants producing or using corrosive chemicals. Its permanence and beauty in decorative effects and design of panelling and ornament are well known, and its value as a coating over other base metals to prevent corrosion has long been established.

Sheet zinc is much used for cornice work, gutters, leaders and roofing. Pure sheet zinc is used generally in conjunction with other materials as a covering or lining agent.

Copper is a very durable metal, is one of the most adaptable to building uses in itself or in alloy and is only slightly affected by atmospheric or climatic conditions. It is extensively used for cornice and roofing work, and as a "Kalamein" covering for doors and windows.

Brass is much used in the arts in cast or wrought form because of its color and malleability, but has a tendency to tarnish. Bronze is peculiarly adapted for use in building finish and design in cast or wrought form. The application of bronze and brass in building construction is adaptable for spandrels, windows, doors, railings, lighting fixtures, hardware, etc.

Aluminum is used with a small percentage of other elements added, to increase its physical characteristics. It resists atmospheric corrosion to a considerable degree, is stainless except in abnormal climatic and atmospheric conditions, can be fabricated by all methods common to metals and is low in cost compared with other materials possessing less advantageous qualities, is manufactured in various forms—cast, wrought and extruded—affording almost unlimited opportunities for its use in building design and finish, and lends itself to structural use where decreased weight is desirable. Care must be taken to properly insulate this material from other materials or alloys with which it may come in contact to overcome the possibility of electrolytic action.

Monel metal possesses great tensile strength and resistance to a remarkable degree. Monel metal tarnishes easily, particularly under atmospheric conditions where salt air is prevalent, but has good corrosive resisting properties.

Stainless steel is high in corrosive and heat resistance, workability, uniformity and perfection of surface. When polished on exposed surfaces, it retains an untarnished finish for a long period of time, even when exposed to rain and atmospheric conditions in the vicinity of salt water. It is considerably used in structural shapes and sections, but is not easily adapted to use in ornamentation, except when cast sections or ornaments are used.

Nickel is hard, ductile and malleable, is known to be somewhat magnetic and is capable of taking a high polish. Oxidation in nickel is very slow. This metal as a plating agency has an extensive application.

Chromium is used extensively for plating. In its pure state it has no value except when electro-plated on metal. It is also used as an element in the manufacture of stainless steel, to which it adds hardness and increases resistance to corrosion.

The continued use of metals for design, ornamentation and finish, both on the interior and the exterior of buildings, requires careful study. Not only must the cost, weight, ease of fabrication and assembly, strength and other physical characteristics be taken into account, but careful consideration must also be given to their corrosive resisting and non-staining qualities, their action upon adjoining materials, such as stone and brick of the lighter textures, and other similar properties.

Generally, the various metals under discussion when used for interior use do not become involved in chemical phenomena such as oxidation to any serious extent, so far as the metals themselves or adjoining perishable materials subject to staining are concerned. Care must be taken in combining various metals to build up ornament or execute designs so that the possibility of galvanic action or electrolytic corrosion may be prevented. This applies both to interior and exterior work.

Experience in the application of metal and metal alloys in building construction which have stainless or rust-resisting qualities to a more or less degree covers a broad field. These materials, however, should be selected for their general merits for the particular use required, giving consideration to cost if required.

Recommendations

The Committee submits report as information only account lacking sufficient data as to life of some metals reported on, and recommends subject be discontinued.

REPORT OF SPECIAL COMMITTEE ON CLEARANCES

A. R. WILSON, *Chairman;*
JOHN E. ARMSTRONG,
H. AUSTILL,
R. C. BARDWELL,
E. H. BARNHART,
J. G. BRENNAN,
GEO. S. FANNING,
C. H. TILLETT,
C. J. GEYER,
G. A. HAGGANDER,
W. S. H. HAMILTON,
M. J. J. HARRISON,
MEYER HIRSCHTHAL,
C. R. KNOWLES,
J. M. METCALF,
G. A. RODMAN,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully submits the following report:

In 1914, the Committee on Maintenance of the former American Railway Association compiled data relative to clearances established by the various railroads for switchstands, signal stands, platforms, platform shelters, mail cranes, water columns, coal chutes, water tanks, etc.

The information was summarized and presented to that association in November, 1914. The Committee on Maintenance reported to the association that the general subject of clearances had been referred to the American Railway Engineering Association for its consideration and recommendation.

In 1917 (see pp. 1255–1260, Vol. 17, Pro. AREA), the American Railway Engineering Association submitted its recommendations on the subject to the American Railway Association, which were approved by its Executive Committee and by the ARA as its recommended practice. The clearances recommended also received the approval of the then Director-General of Railroads, as to railroads under Federal control.

The conclusions of the American Railway Engineering Association on which its recommendations were based follow:

(1) The clearances recommended are based on the present general practice as to dimensions of equipment.

(2) Any attempt to establish a clearance diagram will be wholly futile unless there be established at the same time a corresponding maximum width for the size of equipment.

(3) The logical course is to prescribe minimum clearances only and to place no restrictions whatever as to maximum clearances.

The recommended clearances, referred to above, were promulgated by the American Railway Association in Circular No. 1936, dated November 23, 1918.

In 1922 the Special Committee on Clearances was formed, with instructions to "consider the general clearance diagram adopted in 1917 and promulgated by the American Railway Association, November 23, 1918, as Circular No. 1936 and to make whatever modification in the adopted clearance diagram that are necessary and make a recommendation at an early date."

Subsequent to the issuance of Circular No. 1936, the clearances were revised and added to by the AREA in March, 1931; March, 1932, and March, 1934, in the following particulars:

Clearance Diagram for Bridges and Tunnels—for new construction.
Buildings and Sheds—for new construction.
Warehouse and Engine House Doors—for new construction.

Bulletin 382, December, 1935.

During the past year, it has appeared desirable to your Committee to critically review the established clearances and assemble this data in one place, in order that it might be readily accessible to those railroad officers having need for this important information, even though it involved some duplication. The results of this further study are as shown in Figures 1 to 14, inclusive.

Your Special Committee on Clearances recommends:

(1) That for new construction, the revised clearance diagrams submitted and as shown in Figures 1 to 14, inclusive; and

(a) The clearances on straight track shall not be less than those shown.

(b) On curved track the clearances shall be increased to allow for the overhang and the tilting of a car 85 ft. long, 60 ft. between centers of trucks and 14 ft. high.

(c) The superelevation of the outer rail being in accordance with the recommended practice of the American Railway Engineering Association.

(d) The distance from top of rail to top of ties shall be taken as 8 inches.

(e) Legal requirements to govern when in excess of dimensions shown,

be approved as recommended practice.

Note.—Paragraphs (a), (b), (c) and (d) apply to Figures 1 to 9 inclusive. Paragraph (e) applies to Figures 1 to 12 inclusive.

(2) That these diagrams, Figures 1 to 14 inclusive, and paragraphs (a), (b), (c), (d) and (e) be submitted to the Association of American Railroads, with the recommendation that this data, with data developed by other Sections of the Engineering Division and the Telegraph and Telephone Section, be promulgated in a special pamphlet as the recommended practice of the Association of American Railroads for clearances.

The Special Committee on Clearances,
A. R. Wilson, *Chairman.*

CLEARANCE DIAGRAM
FOR
BRIDGES

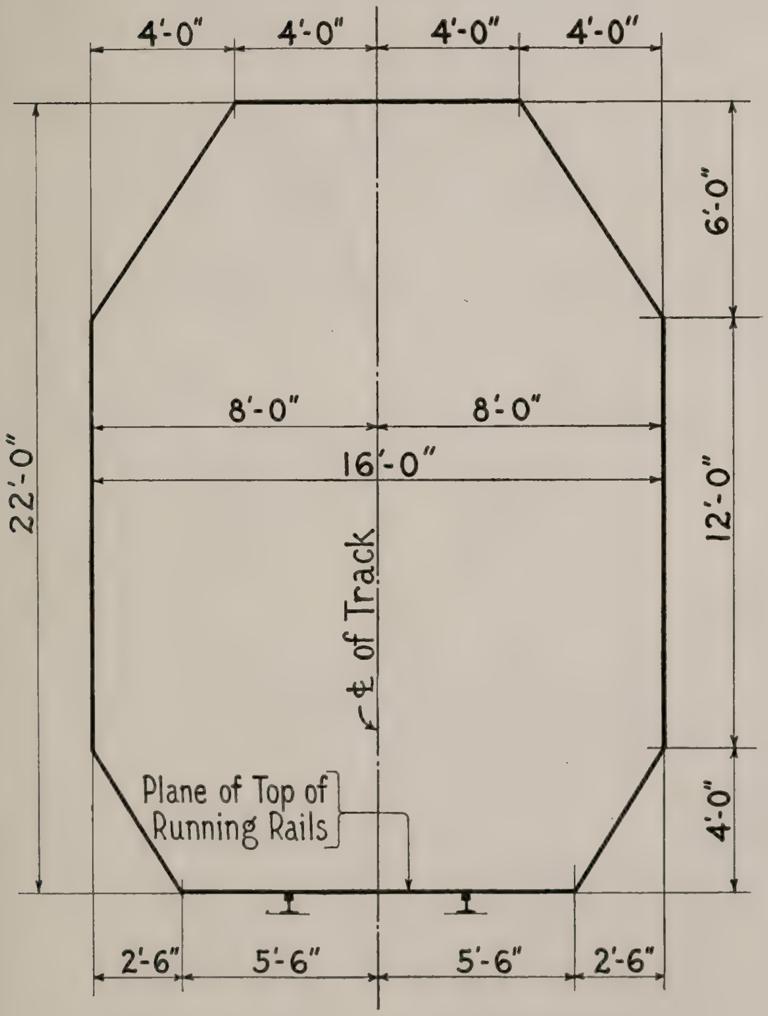


FIGURE 1

Note: For Permanent Structures other than Bridges and Tunnels see Figure 5

CLEARANCE DIAGRAM
FOR
TURNTABLES

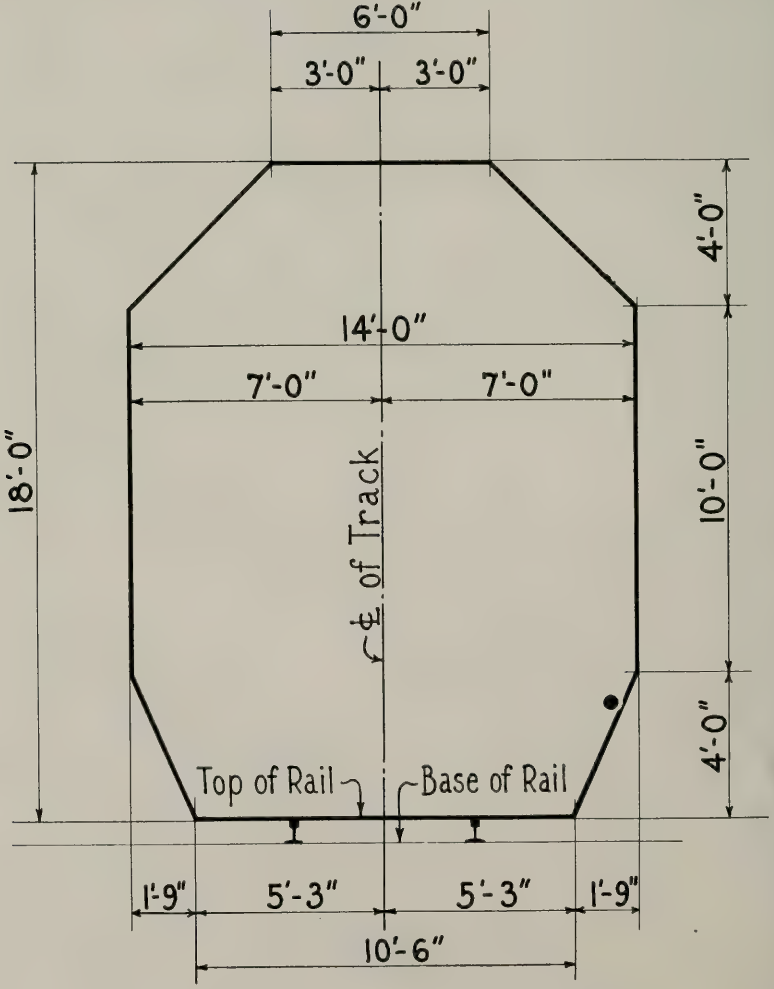
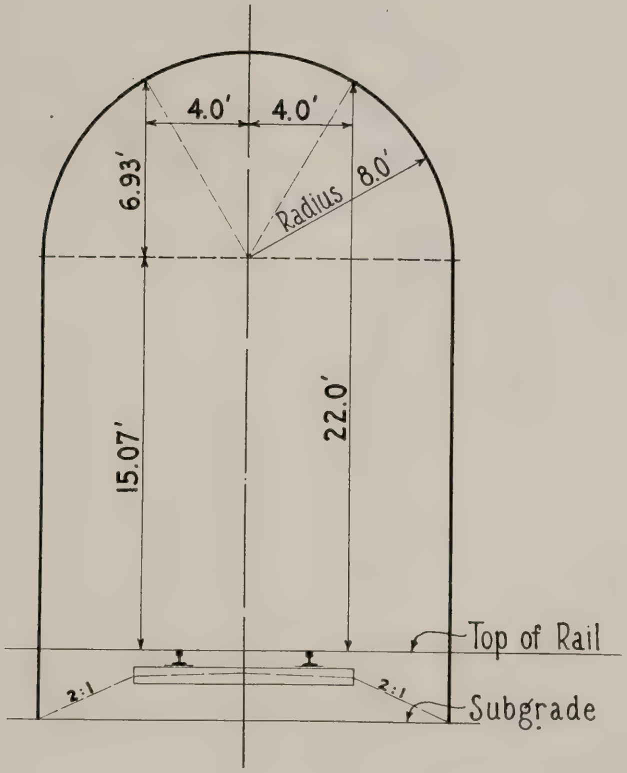


FIGURE 2

CLEARANCE DIAGRAM
FOR
SINGLE TRACK TUNNEL

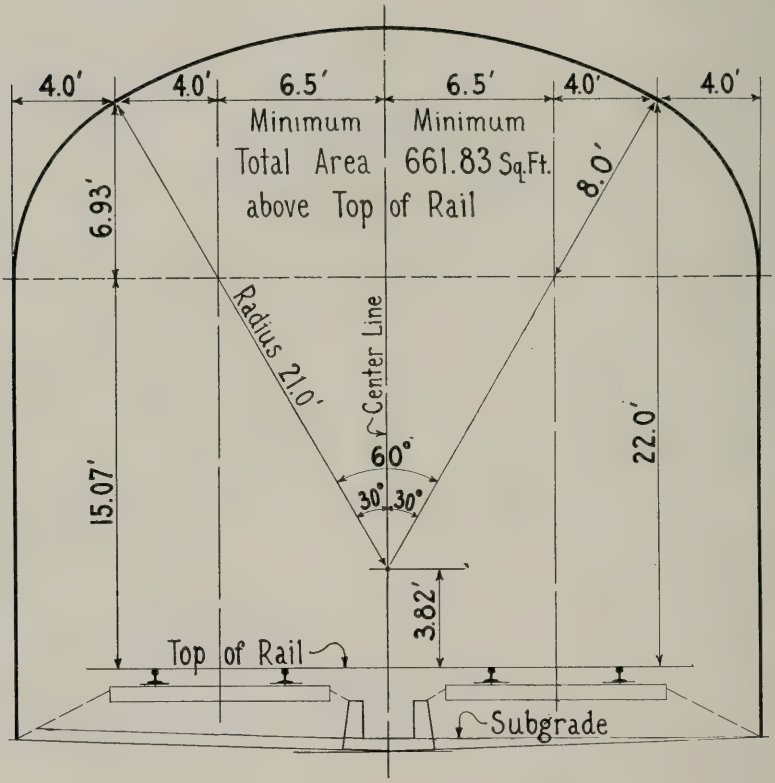


TRACK ON TANGENT

FIGURE 3

Note: For Permanent Structures other than Tunnels and Bridges see Figure 5

CLEARANCE DIAGRAM
FOR
DOUBLE TRACK TUNNEL



TRACK ON TANGENT

FIGURE 4

Note: For Permanent Structures other than Tunnels and Bridges see Figure 5

CLEARANCE DIAGRAM
FOR
PERMANENT STRUCTURES
ADJACENT TO MAIN TRACKS

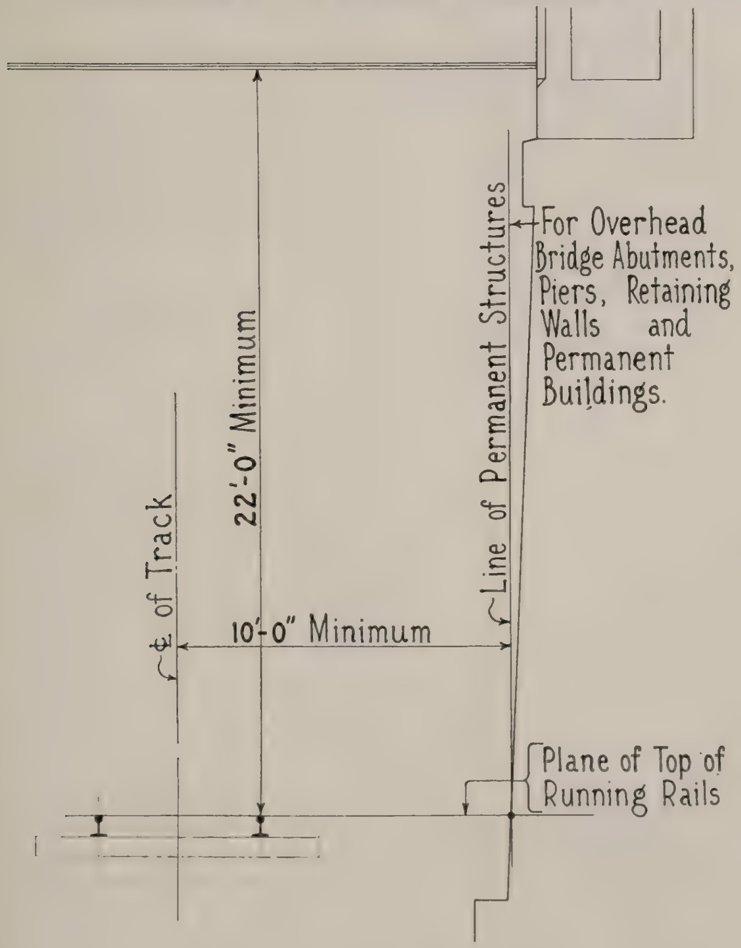

For Overhead Bridge Abutments, Piers, Retaining Walls and Permanent Buildings.
Line of Permanent Structures
22'-0" Minimum
℄ of Track
10'-0" Minimum
Plane of Top of Running Rails

FIGURE 5

Note: For Bridges see Figure 1
For Tunnels see Figures 3 & 4

CLEARANCE DIAGRAM
FOR
BUILDINGS AND SHEDS

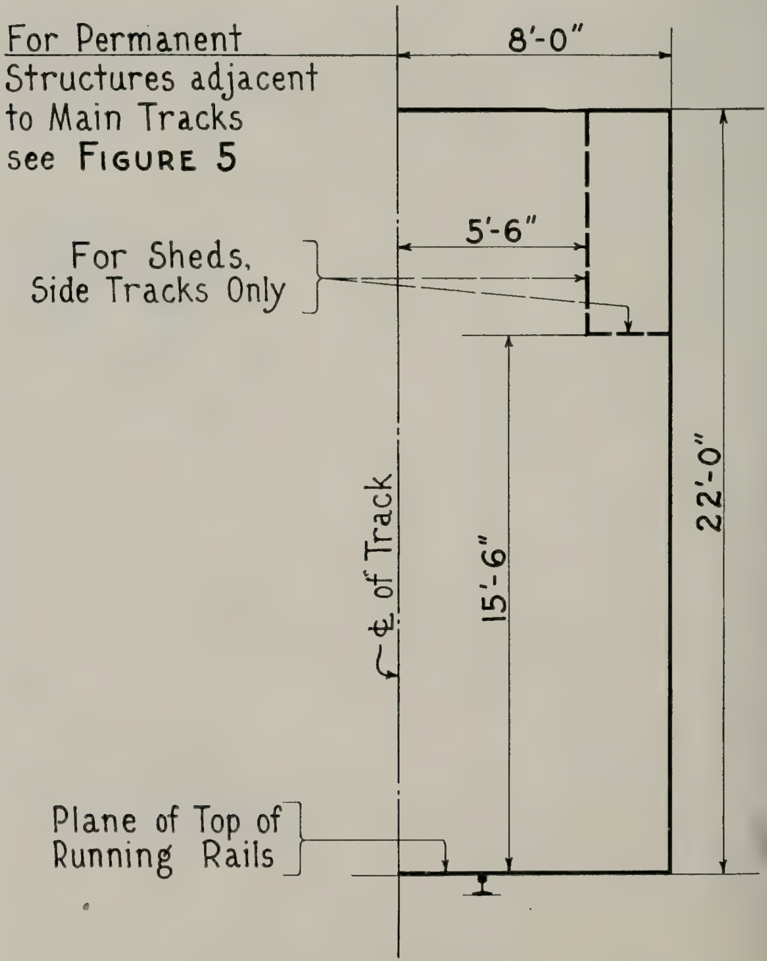


FIGURE 6

CLEARANCE DIAGRAM FOR WAREHOUSE AND ENGINE HOUSE DOORS

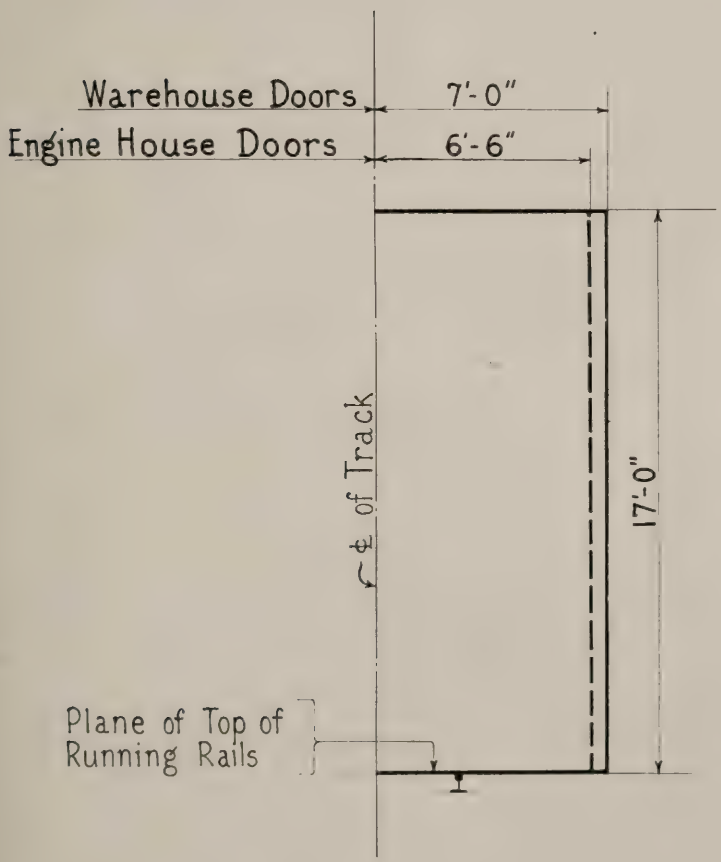


FIGURE 7

CLEARANCE DIAGRAMS FOR PLATFORMS

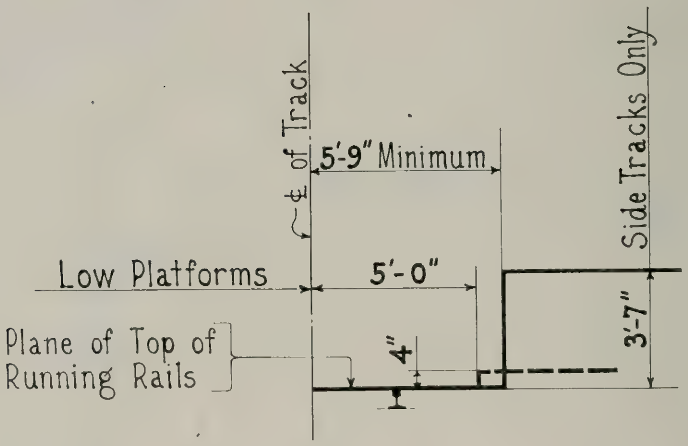
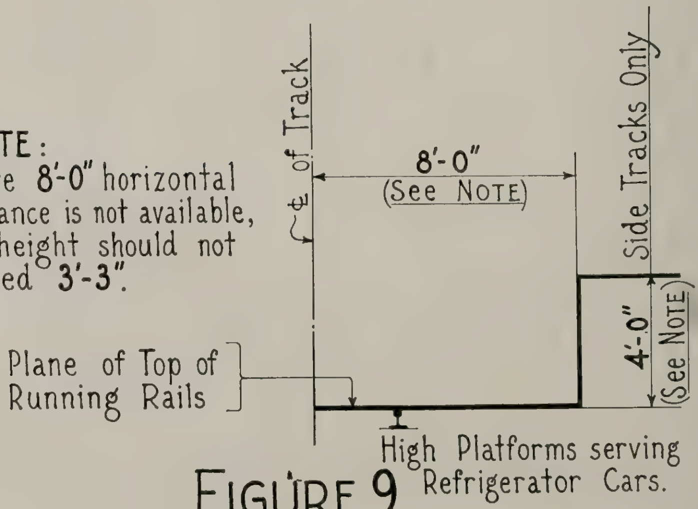


FIGURE 8


℄ of Track
Side Tracks Only
8'-0" (See NOTE)
Plane of Top of Running Rails
4'-0" (See NOTE)
High Platforms serving Refrigerator Cars.

NOTE:
Where 8'-0" horizontal clearance is not available, the height should not exceed **3'-3"**.

FIGURE 9

CLEARANCE DIAGRAM
FOR
TWO-LANE HIGHWAY TRAFFIC

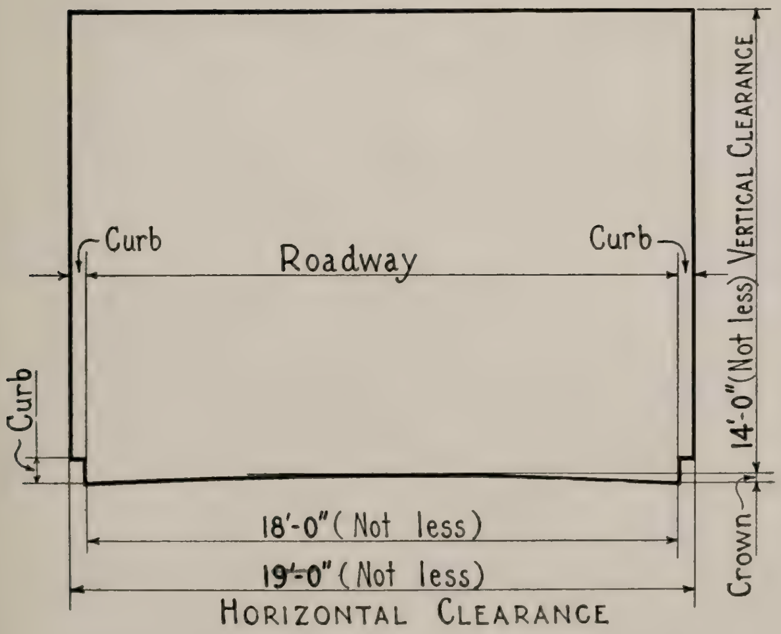


FIGURE 10

A

CLEARANCE DIAGRAM FOR ELECTRIC RAILWAY AND TWO LANE HIGHWAY TRAFFIC

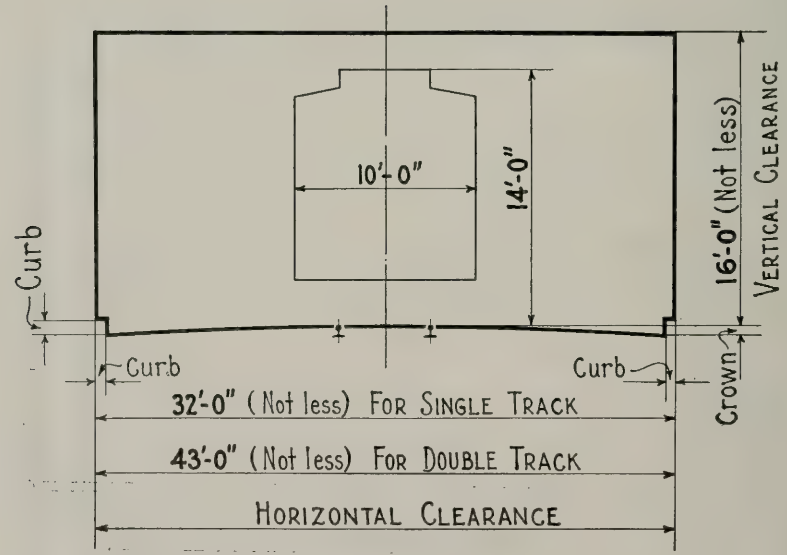


FIGURE 11

CLEARANCE DIAGRAM
FOR
SINGLE TRACK ELECTRIC RAILWAY AND ONE LANE HIGHWAY TRAFFIC

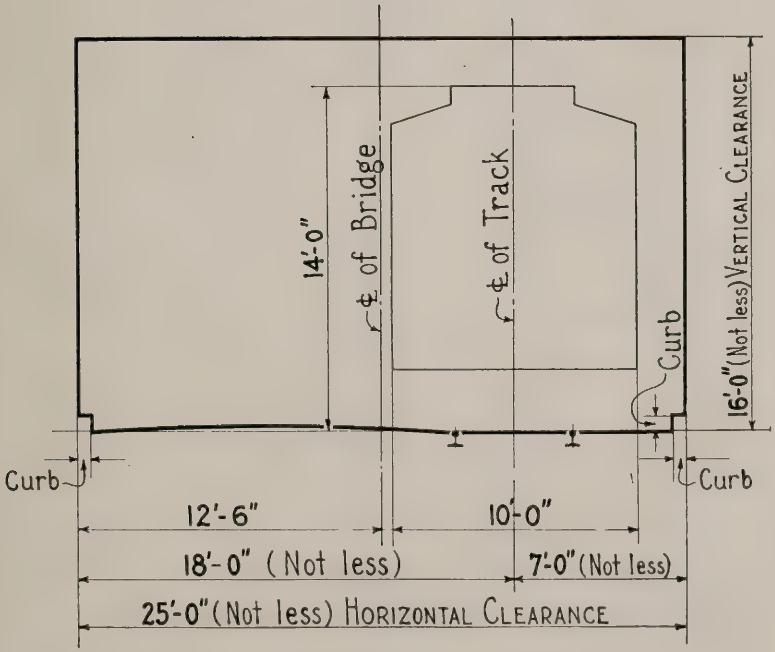
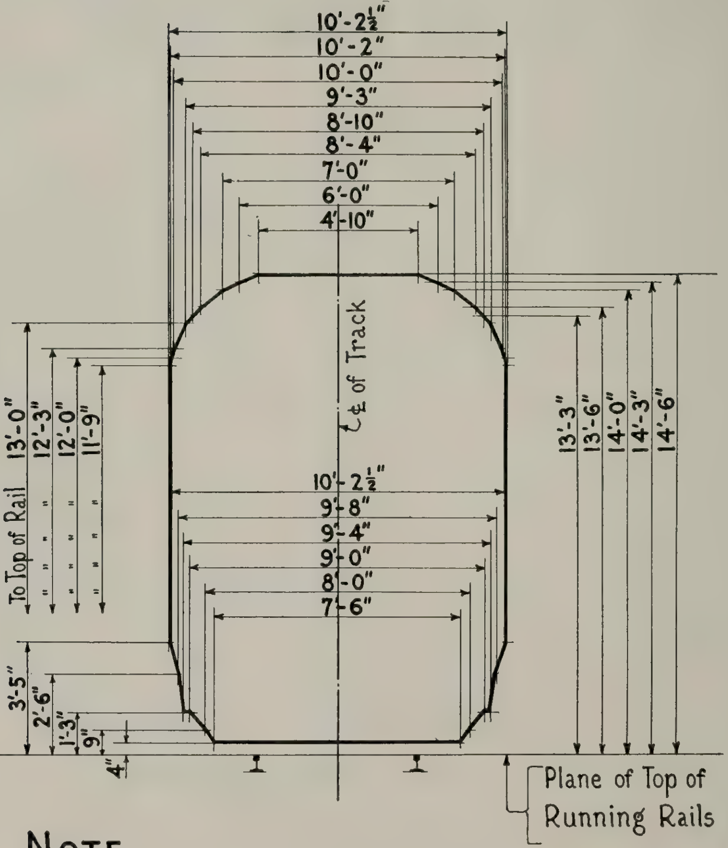


FIGURE 12

EQUIPMENT DIAGRAM UNRESTRICTED



NOTE:

THIS DIAGRAM IS THE SAME AS PLATE B

FIGURE 13

Plate B developed by Committee on Car Construction, Mechanical Division—1920.

EQUIPMENT DIAGRAM

UNRESTRICTED FOR MAINLINES

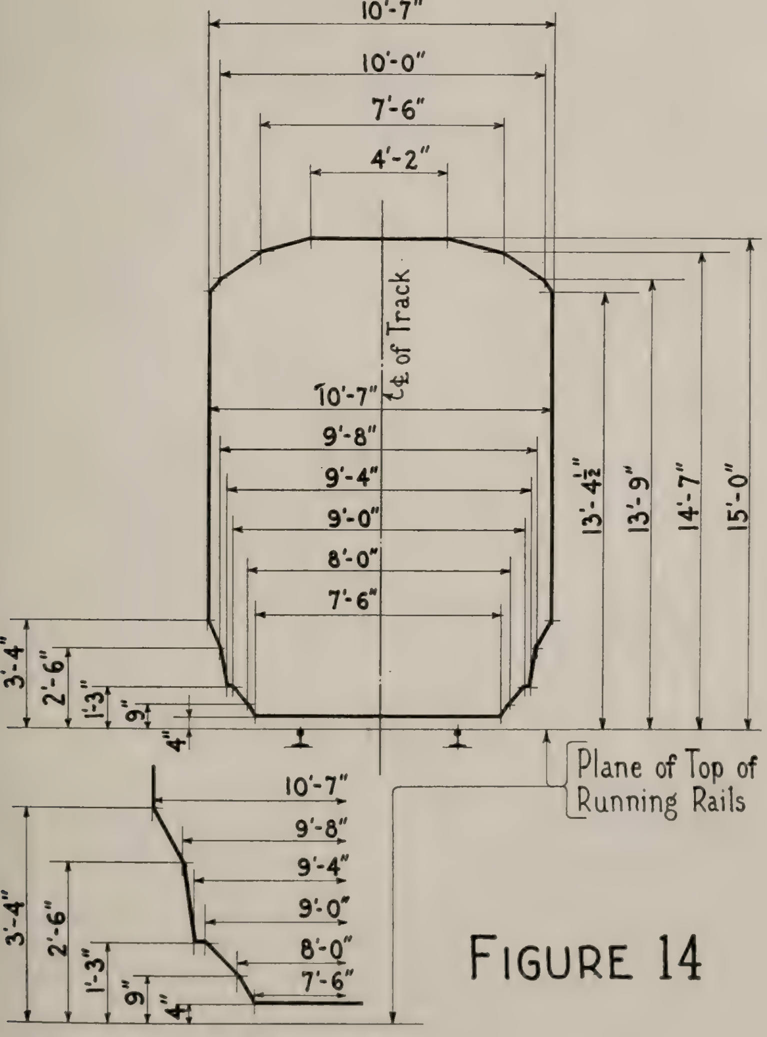


FIGURE 14

DETAIL OF CORNERS

REPORT OF COMMITTEE XIV—YARDS AND TERMINALS

M. J. J. Harrison,
Chairman;
J. R. W. Ambrose,
C. E. Armstrong,
John E. Armstrong,
C. J. Astrue,
H. G. Basquin,
E. J. Beugler,
W. O. Boessneck,
N. C. L. Brown,
H. F. Burch,
W. F. Cummings,
F. T. Darrow,
R. B. Elsworth,
A. W. Epright,
E. H. Fritch,
W. H. Giles,
E. D. Gordon,
R. J. Hammond,
G. F. Hand,
E. M. Hastings,
W. J. Hedley,
H. O. Hem,
W. H. Hobbs,
J. M. Hood,
A. B. Jacobus,
Noah Johnson,
E. T. Johnston,
E. K. Lawrence,
L. L. Lyford,
Hadley Baldwin, *Vice-Chairman;*
C. P. McCausland,
C. H. Mottier,
A. E. Owen,
T. R. Ratcliff,
C. L. Richard,
H. L. Ripley,
H. M. Roeser,
W. B. Rudd,
W. C. Sadler,
C. U. Smith,
E. E. R. Tratman,
H. L. Vandament,
E. P. Vroome,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual (Appendix A).

(2) Hump yards, collaborating with Committee XXI—Economics of Railway Operation. Progress in study—no report.

(3) The expediting of freight car movements through yards, collaborating with Committee XXI—Economics of Railway Operation. Progress in study—no report.

(4) Coal transfer terminals, collaborating with Committee XXV—Waterways and Harbors (Appendix B). Complete and presented as information.

(5) Scales used in railway service (Appendix C). Partially complete with recommended conclusions for publication in the Manual.

(6) Bibliography on subjects pertaining to yards and terminals appearing in current periodicals (Appendix D). Progress report.

The Committee on Yards and Terminals,
M. J. J. Harrison, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

M. J. J. Harrison, Chairman, Sub-Committee; J. R. W. Ambrose, John E. Armstrong, Hadley Baldwin, W. F. Cummings, E. H. Fritch, E. M. Hastings, E. T. Johnston, L. L. Lyford, C. H. Mottier, H. L. Ripley, H. M. Roeser, E. E. R. Tratman.

In view of the practical certainty that a revised Manual will be issued following the 1936 Convention, and bearing in mind the various constructive criticisms that have been made of the 1929 Manual in general and the Yards and Terminals chapter in particular, your Committee has critically reviewed its entire chapter. After much careful study, it was concluded that a general rearrangement would add materially to the value of the chapter. This was undertaken, and the revised chapter is herewith submitted for consideration, with the recommendation that it be accepted as a substitute for the present chapter.

Bulletin 383, January, 1936.

The outstanding change is the breaking-up of the former section entitled "Points to be Considered in Developing Joint Passenger Terminal Projects", and the redistribution of the material therein to other headings. Certain new material will be found in the proposed chapter, and the deletion of certain of the present items is recommended.

The proposed chapter follows.

I—TERMINALS

11) General

a) The designation "terminal" as here employed has a wide range of application. It applies to:

(1) The facilities provided and maintained by a terminal company, or equivalent organization, and operated to accommodate the passenger and freight service handled within or through a given zone served by any number of participating railways.

(2) A similar layout of facilities having to be provided by an individual railway for the accommodation of all its traffic handled in or through a similar given zone.

(3) Any small aggregation of facilities that may be provided either by an individual railway or jointly in behalf of two or more railways, in any case for the accommodation of those functions, or some of those functions, enumerated in the Manual definition, even though for only a relatively very small volume of traffic.

b) This chapter primarily contemplates the establishment of entirely new facilities, but with the intent that its prescriptions shall be applicable as far as conditions permit in any case where existing facilities have to be rearranged, amplified, modernized or consolidated.

c) It aims to meet the strictly engineering problems that, in general and in detail, confront those responsible for the location, design and construction of a terminal, but with due regard for the attainment of expedition and economy in the use, operation and maintenance thereof.

d) The strictly engineering considerations involved in the design, location and construction of terminal establishments are generally substantially the same whether the ownership and use is to be joint or individual. In either case they relate directly to the location and orientation of the terminal plant so as to secure the most convenient and economical access of the lines of railway tributary thereto, for which a belt line may have to be provided in some cases, and especially the providing of those terminal features and their arrangements and capacities required to accommodate expeditiously and economically, and subservient to the public convenience, the traffic involved.

e) Preservation of existing railway routes and of existing facilities is desirable from the standpoint of initial expense, but may be extravagant from the standpoint of operating costs and service efficiency. Careful study should be made to strike a true balance between the two, so that the ultimate of efficiency and economy may be reached; keeping in mind the likelihood of the future growth of business both in total amount, in periodic intensity, in direction, and in character.

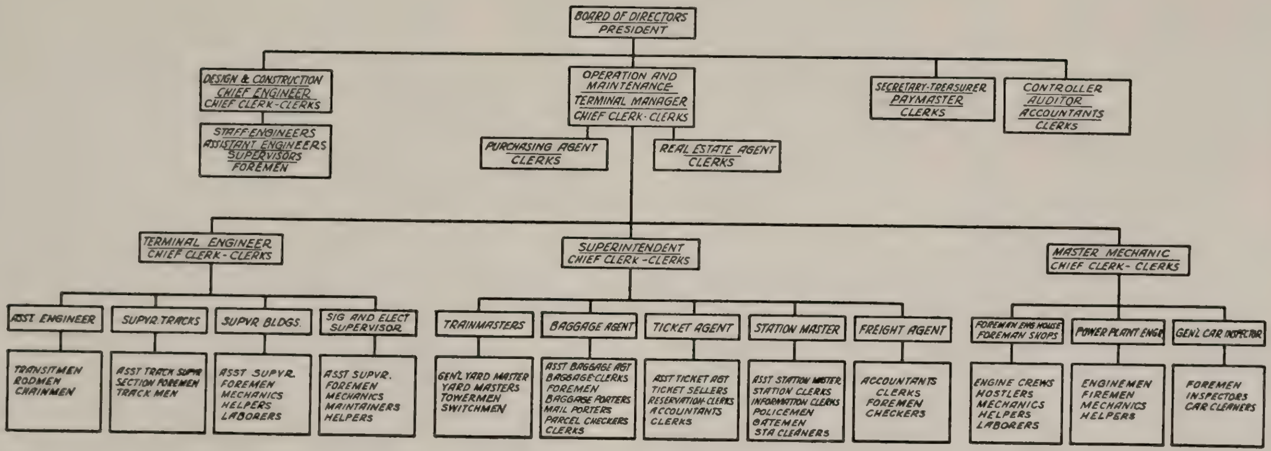
12) Joint Terminals

a) Entrance upon any joint undertaking on a major scale constitutes a step of momentous significance and, accordingly, should wait upon the most exhaustive studies and analyses aimed at a true comparison between the achievements that may be attained under the arrangements to be surrendered and those attainable under that proposed, with due regard both to the local operating cost and capital charges involved and to the conservatively estimated effect in the matter of terminal convenience and expedition.

b) Agreement upon the establishment of a joint passenger terminal is obviously much less involved with difficulties than would be the case with freight facilities, and such establishments have been more frequently consummated, many of them, however, with a distressing increase in the cost of equivalent accomplishment.

c) The assumption that a modern, substantial plant under one management can be operated at smaller expense and with more regularity than can a number of small

TYPICAL OUTLINE OF MAXIMUM ORGANIZATION FOR TERMINAL CONTROL



plants of the same aggregate capacity, rendering an equal service, cannot be relied upon in all cases.

d) Agreement upon joint undertakings may be warranted:

(1) Where a material increase in expedition can be surely anticipated without undue increase in unit cost, all things considered.

(2) Where the existing facilities of the respective railways interested are outgrown and obsolete, and lack of space or extraordinary cost prohibits the modernization and expansion thereof adequate to provide requisite capacity and proper expedition of service.

(3) Where governmental power, or popular demand, has substantially the force of mandate.

e) In any such joint establishment:

(1) A single operating organization should control all activities within the terminal zone. All employees, including employees of the joint users while functioning within the terminal limits, should be subject to the discipline and control of the proper terminal officers.

(2) Commensurate authority should go with responsibility, and vice versa.

(3) The terminal management should ordinarily have sole charge of the maintenance of all property whose use it controls, and with its own forces.

f) The terminal agreement is a matter of fundamental importance. As fully as possible it should be comprehensive and definite in anticipating all contingencies touching the relations of the owners and users with the terminal and among themselves. As every terminal project will largely constitute an original problem, it becomes important in the instant case to examine as many existing agreements as possible, and to consult those charged with administration thereunder concerning especially the weaknesses and omissions therein, in order to make it as sure as possible that the agreement in point will be complete and clear.

II—PASSENGER TERMINALS

21) General

a) The designation "passenger terminal" as here employed includes all the facilities for the passenger station proper, mail and express service, track and street approaches, such other auxiliary or accessory features as may be included within a prescribed boundary or terminal zone, and, where desirable and practicable, a locomotive terminal, a coach yard, and the appurtenant switching facilities.

b) Studies for such a terminal should be made by a committee, representing all the parties at interest, composed of engineering, transportation, mechanical, signal and traffic officers. Preferably the officer to be placed in charge of the property for operating purposes should be made a member of that committee.

c) Consistent with the magnitude and importance of the task, men having expert knowledge of the various phases of the problem should be employed under the direction of the committee to study the whole situation. These experts should determine and report on all necessary requirements of the terminal.

d) The engineer having charge of the design of the contemplated facilities, accompanied when practicable by members of the committee or its representatives, should make investigations by personal inspection of terminal situations somewhat similar to the one in contemplation; talk with responsible officers of similar terminals; examine the facilities there provided and see how they function; obtain comments from the men operating the terminals visited; get their suggestions as to improvements which experience has taught them might be made to advantage. He should also accumulate and study reports that have been written covering particular properties, and also the books and articles that have been written upon the general subject; and seek information from all available sources.

e) The handling of mail and express, and the conjunction thereof with the handling of baggage, are essential and integral parts of passenger terminal operation. The necessary facilities should be planned in cooperation with the express and postal officials concerned.

f) A passenger terminal project should be so located and designed as to coordinate as far as reasonably practicable with other civic activities. Frequently it is found desirable to make general civic improvements at the same time the terminal is being constructed. Modification of street approaches is almost always involved. The costs should be assumed by the parties benefited. Close cooperation between the terminal committee, the Planning Board of the city, Executive Officers of the city, and perhaps other civic groups, is necessary in order that such new legislation as may be necessary shall be fair and equitable to all parties at interest.

g) The design of a passenger terminal should provide for anticipated demands during at least the first twenty years of its life, and provision should be made for such subsequent expansion as may be reasonable under the circumstances.

h) The designer must be mindful that a large passenger terminal is subject to vicissitudes of weather, to delays and derailments to trains, to late connections, to power failures, to surges in traffic, to bad-order equipment, to special trains or cars requiring special handling, to excursion travel, and to jubilees, conventions and special functions at irregular periods.

i) The site for the terminal should have a balanced maximum composed of the following characteristics:

(1) Accessibility—having due regard to modern methods of transportation, land values, and economic requirements.
(2) Sufficient size and suitable shape to provide for a proper number and length of tracks, and to provide for future growth of both.
(3) Ease of approach from all the associated rail lines, without excessive curvature or gradient, and without grade crossings.
(4) Preferably open-air rail approaches, unless all lines are to be electrified.
(5) Possibilities of proper highway approach development without excessive cost.
(6) Proper relation, present and prospective, to rapid transit and surface car lines, etc.
(7) Room for proper by-pass tracks and for the spread of ladder tracks, to provide for free movement and to prevent a tie-up of the yard from derailment at the throat.
(8) Room for auxiliary facilities conveniently located, such as:
    (a) Baggage, mail and express.
    (b) Parking space for Pullman sleepers and private cars.
    (c) Locomotive terminal.
    (d) Coach yard.

22) Track Arrangement

a) The track layout should be designed to permit the required number of incoming and outgoing movements to be made at one time, with a proper margin for delayed trains. Where the crossing of train movements at grade cannot be avoided, crossovers should be so arranged that a derailment will cause a minimum of delay. It is imperative that provision be made for economical, efficient and continuous operation during the rush hour or period of greatest activity.

b) Tracks should be so arranged that the anticipated train movements may be made promptly and economically, and that signaling, if warranted, may be readily provided at any time.

c) Freight or industry connections on the station approaches or on lines within or adjacent to the terminal zone should be so arranged as to avoid or minimize interference with passenger traffic.

d) Loop tracks for turning trains generally expedite service and effect economies.

e) The number of station and approach tracks required to handle a given traffic depends on type of station, location of coach and locomotive facilities, size of station, length of station tracks, character of traffic, design of throat, and method of operation.

f) The through and loop types of station are superior to the stub station from the standpoint of train operation.

g) Sufficient throat tracks should be provided to permit at least two simultaneous parallel movements. The track layout should be sufficiently flexible to provide for complete interchange of routes.

h) A ratio of from 2.5 to 3.0 station tracks to one throat track should be adequate if the throat is properly designed.

i) A sufficient number of station tracks long enough to accommodate the maximum length trains, and so located as to assure flexibility of operation, should be provided. Possibility of future increase in length of trains should be considered.

j) The possibilities of using the station tracks for other service, such as freight interchange, when not in use for their normal purpose, should be studied.

23) Street Approaches

a) Street approaches should receive particular attention and care be exercised to see that they are sufficient in number and width; convenient; so located and designed as to lead from or around, and not directly into, lines of traffic congestion; that foot passengers and vehicular traffic have their own independent lines of travel without the necessity for crossing each other at grade; that ample accommodation for vehicles handling baggage, mail and express be provided at points which will not interfere with the free movement of taxicabs, motor busses, street cars, private conveyances, or foot passengers.

b) The desirability and practicability of providing subways for foot passengers to cross to the opposite sidewalks of adjoining streets should be carefully considered. If provision be not made for this at the outset, pipes, conduits, sewers, etc., may make it difficult, expensive, and perhaps impracticable to do so later.

c) Ample provision should be made for convenient access to taxi service within or adjacent to the station; also for convenient access to street cars, elevated or underground railways, busses, and other local transportation systems. Within reason, such means of access should be under cover.

d) It is essential that taxicabs be able promptly to reach the point where their passengers for the station should alight, and to leave that point to make way for other arriving taxicabs. It is even more essential that the parking line for empty taxicabs permit the prompt picking up of passengers leaving the station via the usual exit, and at the same time not interfere with other vehicular traffic.

24) Station Proper

2401) General

a) The station proper is assumed to include all the facilities required for the complete accommodation of passengers and their belongings between the public entrances and the trains; also such facilities as the railway company shall have to provide for the handling of mail and express. It comprises:

(1) The main building, in which is included all the facilities meeting all possible proper demands upon the railway company of passengers prior to their departure or subsequent to their arrival on trains, including facilities for the receipt and delivery of checked hand baggage and also other checked baggage if space and convenience economically permit;

(2) All thorofares connecting the main building with the station platforms, such as stairways, elevators, ramps, and other passage ways and outside concourses, where provided, including all housing and shelter thereof;

(3) The station tracks and the appurtenant platforms on which passengers, baggage, mail and express are loaded upon or unloaded from trains on the station tracks, including the elevators, ramps, or other runways having to be provided by the railway company, upon which baggage, express and mail are trucked to or from the station platforms, including all housing and shelter thereof.

(4) All other buildings having to be provided by the railway company to accommodate the assembly and the public receipt and delivery of baggage, express or mail for movement or after arrival on trains at the station.

(5) All roadways, platforms and parking spaces having to be provided by the railway company to accommodate taxicabs and other public vehicles and private vehicles, handling people to and from the station, including all housing and shelter thereof not embraced in the main building.

2402) Main Building Areas

a) In the ideal arrangement, the principal floor areas will be required for the lobby, the general waiting room or rooms, and the passenger concourse, the last two being either in separate areas or a common area, according to circumstances, the combined function being generally desirable where practicable. An ample corridor should lead from the lobby to the waiting rooms and passenger concourse. The separate men's and women's retiring rooms should preferably open upon such corridor and be connected privately with their respective toilets and lavatories.

b) All of the essential functions of the main building should be served on a common floor level, or levels so nearly common as to be connected by moderate ramps, and so related if possible to the station track level that no stairways shall be required to reach the station platform level in stub end stations or to reach the thorofares over or under the tracks, as the case may be, in through stations.

c) The lobby should front upon the principal public entrances and exits, and it, solely or together with the corridor, should be the business area of the station. The principal station facilities, such as information booths, ticket office, baggage check counter, parcel check room, etc., should be located in proper sequence along the line of travel and clearly indicated to avoid confusion and reduce the walking distance of passengers to a minimum.

d) An adequate and conspicuous bulletin board should be provided.

e) The general waiting room, if only one is provided separately from the passenger concourse, may well be placed at one side of the line of travel but as convenient as practicable to the passenger concourse.

f) If the function of the general waiting room is to be served in common with that of the passenger concourse, provision must be made for all the requirements of a waiting room, with seating facilities so situated as not to intrude upon the maximum areas required for passage of persons to and from the train gates or for those assembling thereat.

2403) Concourses

a) Unless its function is combined with that of a waiting room, a separate passenger concourse is essential in a large station. Such a concourse is used effectively in many stations as a passageway which permits arriving passengers to reach the street or departing passengers to enter from the street without passing through the lobby.

b) It should be possible, and is exceedingly advantageous in the case of suburban service, for passengers to proceed directly to and fro between the passenger concourse and the street without passing through waiting room or blocking its exits.

c) The elimination of conflicting lines of travel is very desirable and should receive careful study in the design of the station, particularly as regards the segregation of inbound from outbound passengers, and of commuters from through passengers.

d) The required clear width of passenger concourse depends upon the character and amount of traffic and the number of its entrances and exits. The concourse should be large enough to permit the gathering of a full trainload at a gate without a blockade, but should be so arranged that it will not be a convenient thorofare for people who are not passengers.

e) A train concourse is advantageous, as it permits serving of one station platform by several gates or, conversely, the serving of several platforms from one train gate. In stub stations it permits trucking from one platform to another without entering the passenger concourse.

f) A clear width of 20 feet for a train concourse is adequate if it is not used extensively for trucking.

2404) Ticket Offices

a) Ticket offices should be located adjacent to the direct line of travel, so arranged that passengers waiting to secure tickets will not interfere with the general flow of traffic.

b) Windows opening directly on to the passenger concourse for the sale of local tickets are desirable.

c) Where a large number of commutation tickets are issued during the last two or three days of the month, portable booths located in the passenger concourse may be desirable.

2405) Parcel Rooms

a) The parcel check rooms should be easily accessible for both inbound and outbound passengers, and should have facilities for handling parcels quickly. Where the amount of business justifies, separate counters should be provided for receiving and delivering parcels.

2406) Toilets

a) The practice of installing pay toilets is increasing. They are favorably considered where installed, and are the source of a substantial revenue. However, there should be an adequate number of free toilets and washing facilities.

2407) Concessions

a) Concessions of proper character have proved profitable in most stations and are desirable, not only from a revenue-producing standpoint, but as a facility which adds to the comfort or convenience of the passenger.

b) The number and character of these concessions can be greatly expanded in terminals located in cities of large size, with benefit and profit to all concerned.

c) Concessions, to be successful, must be so located as to be conspicuous and easy of access. They must be neat and attractive in appearance and well lighted, and concessionaires should be experienced, responsible and progressive.

d) Booths opening directly on to the corridor, where service is rapid, appeal more to the commuter, while stores appeal to the through traveler and particularly to the transfer passenger who has time to spare.

2408) Office Space

a) The practice of constructing rentable office space in connection with passenger stations under proper circumstances offers opportunities for assisting in carrying the interest charge resulting from the construction of stations.

b) If the station building is surmounted by an office building, the entrances to the latter should be independent of the station so that office employees will not be required to pass through the station. Consideration, however, should be given in the design of certain station facilities to the possible patronage by occupants of the office building.

2409) Taxicab Facilities

a) The extent of cab facilities depends on the size of the city, character of taxicab service, and other means of local transportation. In cities where good taxicab service is provided at a reasonable rate, an ever-increasing percentage of passengers is using that service as a means of reaching and leaving the station.

2410) Station Platforms

a) Combined passenger and trucking platforms for normal conditions should be at least 20 feet in width, assuming a row of columns located in the center of the platform.

b) Exclusive passenger platforms should have a minimum width of 13 feet, which is sufficient to accommodate the passengers from one arriving train, one line of travel for passengers to a departing train, and a row of columns in the center of the platform. This width will normally meet all requirements for through passenger train operation, as it is seldom necessary to berth two arriving trains simultaneously at the same platform.

c) Exclusive trucking platforms should have a minimum width of 11 feet to permit two loaded trucks to pass. In stations where the volume of trucking is sufficient to justify providing for three trucking lanes, to avoid the possibility of blocking the platform when two trucks are serving cars on the opposite sides of the same platform, a minimum width of 16 feet should be provided. If columns are necessary on the platform, they should be so located as not to interfere with the trucking lanes, and the platform widths should be increased accordingly.

d) In combined passenger and trucking platforms in through stations, it is desirable to have a clearance of approximately 6 feet on one side of the stairs to permit trucking operations past the stairs.

e) In terminal stations, or in stations where a large number of passengers must be handled quickly, the desirable height of platforms used by passengers is that of the car floor, as the hazard and inconvenience resulting from the use of car steps are eliminated, and the handling of passengers is expedited. However, high platforms interfere to some extent with the switching and inspection of equipment.

f) In a through station the location on the station platform of the approach to the concourse has a bearing on the required capacity of the approach. If it is located at the end of the platform, the concentration will be but one-half as intense as if it is located at the middle of the platform, although the duration of the maximum intensity of congestion will be much less in the latter case than in the former. If a double approach is located at the center, the intensity of the concentration will be the same as in the first case, and the duration of the maximum intensity of congestion will be the same as in the second case.

g) Separate platforms for passengers and trucking, if both are of adequate width, will increase total width of platforms, total space occupied, and costs of construction, when compared with combined platforms. Separate platforms, however, will eliminate the possibility of interference between passengers and trucking, which is very desirable, and which may be justified under certain conditions and volume of traffic.

h) The determination of the type of platform (i.e., combined or separate trucking and passenger) best suited to a particular location is dependent upon the character and volume of the various types of traffic handled, the type of station (i.e., stub, through or loop), the location and type of approaches to the platforms for the various kinds of traffic, the relation of the various approaches to each other, the relative lengths of platforms and trains, space available for station track and platform development, and the method of operation. These various factors are discussed in detail on pages 488–547, Vol. 25, 1924 Proc. Because there are so many variables involved, no general conclusion can be reached as to the most desirable type of platform to be installed. All factors affecting a particular location must be analyzed before this determination can be made.

i) Combined platforms will not result in objectionable interference between passengers and trucking operations, and, when compared with separate platforms under the same conditions, will either effect economy of space and costs of operation or make possible a more liberal width of platforms, in the following cases:

(1) Stub stations in which all trains are backed in.

(2) Loop stations in which all trains move in the same direction, provided the passenger and trucking approaches to the platforms are properly located to avoid interference.

(3) Through stations with passenger approaches located near the middle of the platforms and with trucking approaches located at both ends of the platforms, so as to avoid trucking from one end of the platform to the other, and with platforms of sufficient length in excess of length of trains to eliminate spotting passenger carrying cars at the end zone of the platforms when that zone is being used for trucking.

j) Combined platforms will result in interference between passengers and trucking operations, unless the latter are delayed until the platforms have been cleared of passengers, and separate platforms should be installed, in the following cases:

(1) Stub stations where arriving trains head in.

(2) Through stations with platforms of same length as trains and with passenger approaches located at the middle of the platforms. Interference will be greatly reduced in this case by providing trucking approaches at both ends of the platforms.

(3) Through stations at which two trains are berthed simultaneously on the same track so that, in effect, the relation of the trains with respect to the passenger approach simulates that in a stub station where arriving trains head in.

k) In the large metropolitan areas the character and volume of arriving mail may justify its handling by belt conveyors. While belts are adaptable to either combined or separate platforms, their use in connection with combined platforms is particularly advantageous, as one belt between adjoining tracks can very satisfactorily be used to serve those tracks, while mail not adapted to handling on the belt can be unloaded on to trucks on the platform while other mail is being thrown onto the belt.

2411) Elevators and Escalators

a) Baggage elevators are desirable at both ends of combined passenger and trucking platforms in large passenger stations where trains operate in both directions through the station, to reduce the interference between trucking operations and passengers.

b) For heights less than 25 feet under normal conditions, passenger elevators or escalators are not recommended as approaches to individual passenger platforms. They may be desirable as a supplement to stairs for the use of the aged and infirm.

c) If, instead of one passenger elevator for each platform, a battery of elevators can be arranged in sufficient number and approachable from all tracks, as might be possible in a stub terminal, so that a minimum amount of waiting will be occasioned, their use might be justified.

d) A single elevator or escalator should not be relied upon as the sole means of approach to a station platform.

e) Escalators have a carrying capacity of approximately 33 passengers per foot of width per minute. They are well adapted to suburban service, but there is some question as to their practicability for through passenger service.

2412) Passenger Ramps

a) Ramps furnish ideal means of handling passengers as an approach to passenger platforms if they can be so installed as not to increase materially the distance traveled by passengers, and do not materially decrease the space on the station platform available for the accommodation of trains. Good results can be accomplished in many cases by the use of both stairs and ramps in the approach to the platform.

b) The gradient for passenger ramps preferably should not exceed 10 per cent.

2413) Trucking Ramps

a) Ramps are a very desirable means of providing vertical transportation for trucking operations, if the design of the station is such as to permit their installation without a material sacrifice in space.

b) A gradient of 7 per cent is the steepest yet used to any extent for trucking ramps. This gradient should not be exceeded, though it is possible that trucking ramps may be operated successfully with maximum gradients of 8 per cent.

c) In stub terminals where separate passenger and trucking platforms are used and the baggage, mail and express facilities are located below the tracks, the utilization of the end of the exclusive trucking platforms adjacent to the concourse permits the installation of trucking ramps without sacrifice of space.

d) The minimum clear width which should be considered for trucking ramps designed to accommodate one line of traffic is 6 feet, and for two lines of traffic is 10 feet.

2414) Characteristic Requirements of Through Passengers

a) Transfer passengers occupy a station for a maximum length of time and require more extensive facilities per passenger than resident through passengers.

b) Decreasing the time interval between incoming and outgoing trains decreases requirements per passenger for waiting room space and for certain other facilities.

c) Increased business tends to increase the number of trains, decrease the waiting time, and equalize the spread of minutes-waiting per passenger over the rush hour period.

d) The number of passengers handled during the rush hour does not alone determine the size or number of facilities required. Local conditions must be studied, as they affect requirements for any particular situation.

e) The size or number of facilities must be modified to make allowance for:

(1) Time of arriving and departing trains, and the span in minutes between them.

(2) The ratio between passengers commencing or terminating their journey and transfer passengers.

(3) Number of hold-over passengers arriving or departing outside of the rush hour but occupying space and requiring service during a portion of the rush hour.

(4) Departure from a reasonably uniform spread of passengers entering and departing within the rush hour.

2415) Characteristic Requirements of Suburban or Commuter Passengers

a) Suburban passengers occupy a station for a minimum length of time, occupy less space, and move faster than the through passenger, and therefore requirements in the way of station facilities per passenger are substantially less for a suburban passenger than for a through traveler.

b) When suburban business is heavy, it is desirable to separate the through and suburban service, as their requirements are not similar. This may be done by handling the two classes of service at:

(1) Different levels. This requires electrification.

(2) Different sides of the station.

(3) Different stations, one beyond the other.

c) Indicator boards are the only directional information required, as a rule, by commuters. They should show track number, scheduled leaving time, and essential identification of train.

2416) Relative Size of Facilities

a) A series of tables and diagrams showing size or number of facilities required for varying proportions of mixed through and commuter service is shown on page 862 and pages 899 to 926 of Vol. 24, 1923 Proc. See also pages 972 to 988 of the 1929 Manual.

b) The relations which should exist between business handled and the size of facilities is subject to variation due to local conditions, class of traffic, type of service rendered, outside competition, large variation in estimates of normal rush-hour business handled, and the varying ideas of what constitutes adequate service.

c) The following Table A represents under average conditions the relation which should exist between business handled and the size of through passenger (not suburban) station facilities.

(Table A p. 967, Manual)

2417) Time-Space-Speed Studies

a) Under normal conditions passengers discharge from trains to station platforms at approximately the following rates per single car exit:

(1) Onto low platforms:
  - (a) From Pullmans (after hand baggage has been unloaded)—one passenger every 2.6 seconds.
  - (b) From day coaches—one passenger every 3.0 seconds.
  - (c) From suburban coaches with exit doors 2.4 feet wide—one passenger every 1.8 seconds.
  - (d) From suburban coaches with exit doors 3.4 feet wide—one passenger every 1.4 seconds.

(2) Onto platforms at car floor levels:
  - (a) From suburban coaches with exit doors 2.4 feet wide—one passenger every 1.1 seconds.
  - (b) From suburban coaches with exit doors 4.0 feet wide—one passenger every 0.8 second.

b) Speeds of passengers on station platforms under normal and satisfactory conditions are approximately as follows:

(1) When moving unrestricted as individuals:
  - (a) Through passengers—4.2 feet per second (2.9 miles per hour).
  - (b) Suburban passengers—5.5 feet per second (3.7 miles per hour).

(2) When moving en masse:
  - (a) Through passengers—3.7 feet per second (2.5 miles per hour).
  - (b) Suburban passengers—5.1 feet per second (3.5 miles per hour).

c) The platform space utilized by passengers when moving in a compact mass, but without objectionable congestion, is approximately as follows:

(1) Through passengers—15 square feet per passenger moving 220 feet per minute.

(2) Suburban passengers—10 square feet per passenger moving 300 feet per minute.

d) Capacities of station platforms in discharging passengers are approximately as follows:

(1) Through passengers—15 per foot of width per minute.

(2) Suburban passengers—30 per foot of width per minute.

e) The carrying capacities of stairs decrease with increase in height. For a height of 20 feet, the carrying capacities with traffic in one direction are approximately as follows:

(1) Through passengers—10 per foot of width per minute.

(2) Suburban passengers—18 per foot of width per minute.

f) Passenger ramps of 10 per cent gradient have a carrying capacity approximately as follows:

(1) Through passengers—15 per foot of width per minute.

(2) Suburban passengers—30 per foot of width per minute.

g) The rates of movement of suburban passengers which may be expected are approximately as follows:

(1) Through turnstiles (5.3 feet in diameter)—50 passengers per minute.

(2) Through single swinging doors (3.0 feet wide)—77 passengers per minute.

(3) Through double swinging doors (each 3.0 feet wide) — 117 passengers per minute.

(4) Through ticket gates (each ticket punched)—46 passengers per minute.

(Page 970, Manual)

(Diagram T—Time Required to Pass Suburban Passengers through Gates or over Stairs or Ramps of varying Widths)

(Page 971, Manual)

(Diagram U—Unloading and Traveling Time Chart for Suburban Train—Stub Terminal—Low Platforms)

2418) Air Rights

a) At passenger terminals centrally located in the larger cities, space over the station or approach tracks can often be made available, with advantage and profit, for commercial purposes such as postoffices, office buildings with store frontage on the streets, hotels, certain manufacturing enterprises, and the like. These will help materially in carrying the heavy capital values and tax assessments for the real estate occupied.

2419) Communication Facilities

a) Teletype machines, telautographs and pneumatic tubes may be used to advantage to supplement telephones for the rapid transmission of operating information between train directors, station master, information booth, bulletin board and other strategic points.

25) Coach Yards

251) General

a) It is extremely desirable that coach yards and their appurtenant facilities, incidental to car inspecting, repairing, battery charging, cleaning, icing and watering, and all servicing of sleeping, dining and Pullman cars, should be an integral feature of every large passenger terminal, whether or not more than one railway is accommodated, and whether or not the forces so engaged are in charge of the terminal management.

b) In some joint terminals each line retains jurisdiction of all such forces provided for servicing its own equipment. The Pullman Company always does so. The plan of having all servicing of railway equipment performed with terminal forces would seem in any case to deserve consideration, although either plan may be made to work smoothly and efficiently.

c) It is definitely preferable to have all coach yard switching performed by and under full control of the terminal management in all cases of joint operation where the coach yard is an integral part of the joint terminal, but not otherwise ordinarily.

252) Layout and Details

a) The coach yard should be placed convenient to the station and mechanical facilities.

b) The location of a coach yard should be determined by the economic balance between the following factors:

(1) Available sites.

(2) Land values.

(3) Cost of construction.

(4) Convenience to the station and other facilities.

(5) Cost of moving equipment between station, coach yard and engine house.

c) The capacity required in a coach yard depends upon:

(1) Number of cars and trains to be handled.

(2) Class of equipment.

(3) Standard of maintenance.

(4) Length of layover.

(5) Frequency of cleaning.

d) It is common practice to hold trains for cleaning and waiting for less than 24 hours on one track.

e) There are two general types of coach yard layouts: Stub track and through track. There is also an intermediate type made up of through tracks, but operated generally as two systems of stub tracks. Operation is most efficient in a system of through tracks.

f) Tracks of equal length and equal to the length of the longest trains give greatest operating efficiency.

g) A spacing of 18 feet between track centers has proved ample. Where land values are high, spacing may be reduced to 16 feet or to alternate spacing of 14 and 16 feet.

h) Tracks should be arranged in groups at the leads to facilitate switching. Auxiliary leads and tail tracks of ample length should be provided:

i) Curvature of tracks should not exceed 12°34′ through turnouts or otherwise.

j) Coach yard tracks should be level, but in no case on a gradient exceeding three-tenths per cent.

k) A wye or loop track should be provided for turning equipment. Movements on a loop track are more expeditious.

l) Special tracks for making up or breaking up trains are sometimes required.

m) Only light or running repairs are made in a coach yard.

n) The track bed and platform bed in coach yards should be well drained.

o) Platforms should be placed between all tracks.

p) The platform should be even in height with the top of rail. The edge of the platform should be five feet six inches from the center of the track. The platform should be crowned 3/16 inch to the foot.

q) Water hydrants should be placed a minimum distance apart equivalent to the average length of cars. It is usual practice to place these in alternate spaces between tracks. However, there is substantial advantage in locating them between all tracks.

r) Hot water is usually provided in tubs at convenient locations.

s) Air connections for cleaning should be spaced the same as cold water hydrants. For testing air brakes, connections should be provided through a double connection at the center of each track or through single connections at each end of each track.

t) Electrical supply connections should be spaced the same as water hydrants, but a minimum distance apart equivalent to twice the average length of cars.

u) Steam supply connections should be provided in the same manner as air connections for testing air brakes.

v) A service building and storehouse should be provided.

w) At least one drop pit, serving two tracks, should be provided in large yards.

x) Provision should be made to store a sufficient number of car wheels.

y) There should be a building providing space for the necessary shop facilities.

z) Refuse disposal, fire protection and floodlighting should be provided.

III—FREIGHT TERMINALS

31) General

a) The designation "freight terminal" as here employed includes all the facilities provided by a railway company, or by two or more railway companies in common, as the case may be, having to serve any and all handling of freight to or from or through and within a given district on behalf of such railway company or companies.

b) Conditions of demand and feasibility vary through a wide range, and generally each case of constructing an altogether new layout on a large scale, or of remodeling or consolidating an extensive existing layout, constitutes an essentially original problem.

c) The engineer is confronted with the problem of designing various yards, each for its special functions; miscellaneous tracks for particular uses; freight stations for the receipt and delivery of less than carload freight, or for its transfer, or for its storage, or for the special handling of perishable freight, or for the receipt and delivery of carload freight in different categories; icing facilities for refrigerator carload business; engine houses and shops for the housing, servicing and repair of locomotives in service; shops and facilities for the current repair of cars in service; power cranes for the loading, unloading and transfer of bulky or heavy cargo units; weighing facilities; power plants; and a system of thorofare tracks that shall weave this complex assemblage into a unity of smooth and expeditious performance.

d) Each of these features and its appurtenances, with a full knowledge of the average and maximum demands to be made upon it, must be carefully designed so as expeditiously and economically to fulfill its particular functions.

e) While the attainment of economic efficacy is of weighty importance in the design of the terminal features individually, even this, except possibly as to minimizing investment, is of relatively secondary importance in comparison with the necessity for their correct interrelation in the complete assembly. This involves, with due allowance for future expansions, the proper placement of each feature in relation to the whole, with the closest proximities and minimum distances consistent with securing to each ample room for the free and uninterrupted exercise of its own internal procedure without fouling any common terminal thorofare; also, which is of prime importance, it involves the orderly placement of all these features in the same sequence in space that the movements they are to accommodate properly follow in time so that, insofar as physically possible, all movements through the terminal, as well as to or from or through any tributary facility, shall be straightforward and parallel, unhindered by conflict with counter or cross movements which so often in a terminal of haphazard design are unpredictable, demoralizing and productive of disastrous delay and expense.

f) Terminal delays constitute the most serious handicap to maximum expedition in the railway transportation of freight, or at least the most difficult to overcome with haphazard terminal layouts. Since expeditious movement of freight, more than any other influence, except, perhaps, that of the tariffs, sells the service and augments the earnings, the assurance of a material decrease in essential terminal time will justify a large investment.

g) In any case where relief is or should be sought, where an existing major terminal layout unavoidably imposes intolerable accruals of delay, before attempting to doctor existing facilities in their old place and relation, whether only for an individual railway or involving in the project a permanent consolidation of several lines' facilities, the part of wisdom requires a careful technical determination as to the advisability of providing a layout wholly new and correct in design.

32) Yards and Approaches

a) Freight yards are essentially supplementary units and should be so located, so designed and so operated in relation to each other and to the lines tributary to them as to give the most economical results for the railway as a whole.

b) To meet traffic requirements a yard should be able, even in peak periods, to receive trains promptly upon arrival, perform any auxiliary service (such as icing, feeding and watering stock, making running repairs, etc.), switch cars into their proper classifications without appreciable delay, and dispatch these cars in their proper position in the designated outgoing trains in a minimum of time.

c) The number of yards should be as small as is consistent with the efficient handling of traffic.

d) An additional yard is warranted only when it will result in greater economy than enlargement or reconstruction of, or substitution of a new yard for an existing yard or yards.

e) The type of yard which should be adopted in any given case depends upon the traffic to be handled through it.

(1) A single flat yard is adapted for handling traffic where the total number of cars is small and the number of switching cuts per train is also small.

(2) A double flat yard is adapted for handling traffic where the total number of cars is large but the number of switching cuts per train is small.

(3) A gravity yard or a hump yard is adapted for handling traffic where the total number of cars is large and the number of switching cuts per train is also large—also in special cases where the total number of cars is relatively small but normally received in a short period of time, and the number of switching cuts per train is large.

(4) In special cases, due to the location of the yard, the character of traffic, or the arrangement of schedules, it may be necessary to provide a double flat yard or a hump yard, because of limited time for handling.

f) Future expansion of a yard should be so provided for that the number and length of the tracks in it may be increased as required with a minimum of interference with operation or relocation of existing trackage.

g) An existing yard which is inadequate to handle the existing or immediately prospective traffic should be enlarged, or redesigned and rebuilt, or abandoned in favor of a yard in a different location, according to which of these alternatives will result in the greatest economy.

h) Yard lighting is desirable. The economical distribution of light over the area involved, so as to provide proper intensity of illumination, requires careful design. Recommendations of the Electrical Section should be consulted.

i) A "Catechism" designed to bring out hints as to the improvement in detail of existing yards, and the elimination of slight difficulties which hinder the steady operation of yard service or cause detentions which are small in themselves but become serious in the aggregate, appears on pages 316 and 1121 of Vol. 19, 1918 Proc., and also on page 694 of the 1921 Manual.

321) General Track Arrangement

a) Main tracks should not pass through a yard.

b) Connections to the main track from the receiving or departure tracks should be as direct and simple in alinement as practicable.

c) Crossover tracks should be provided as required to facilitate all normal and regular movements in the yard or between the yard and the main track, and their location should be such as to cause a minimum of interference between different movements which it may be desirable to make simultaneously.

d) Curvature of tracks should not in general exceed 12° 34′ through turnouts or otherwise.

e) The angle between a ladder track and the body tracks should be not less than the angle of the frogs used in the ladder track, and not more than will provide the distance on the ladder track required for the length of turnout used.

f) Ladder tracks should be spaced not less than 15 feet center to center from any parallel track, and when such parallel track is another ladder track, they should be spaced not less than 18 feet center to center.

g) Body tracks should be spaced not less than 13 feet center to center, and when parallel to a main track or important running track, the first body track should be spaced not less than 15 feet center to center from such track.

h) The total standing capacity of the receiving, classification and departure tracks may be roughly assumed to be about equal to the working capacity of the yard.

i) In computing car capacity, 45 feet per car should be allowed for all freight car tracks other than repair tracks.

322) Hump Yards—General

a) When the volume of traffic or other conditions justify a hump yard to meet the requirements (see Vol. 30, 1929, p. 762; Vol. 31, 1930, p. 1014; and Vol. 32, 1931, p. 693, Proc.), the yard layout should provide for a continuous movement of a draft of cars over the hump once it has been started, for the movement of the cars of the draft to their proper position on the different classification tracks without damaging impacts, and for a minimum loss of time between humping successive drafts. Such a layout will result in the nearest possible approach to continuous humping.

b) The design must include the track layout and gradients of all parts of the terminal affecting economical and efficient operation of the hump. To care properly for local conditions, each terminal must be studied independently.

c) The gradient of the receiving tracks and the tracks leading to the summit of the hump should be such that one locomotive can push the maximum train over the hump at the required speed.

d) The track arrangement between the receiving tracks and the hump should provide not only for the release of road locomotives from the receiving tracks with minimum interference with hump operations, but also for moving cars to a point close to the summit of the hump while other cars are being humped, as well as permitting the quick return of the humping engine to the receiving tracks.

e) If the classification tracks are also used as departure tracks, it is desirable to provide additional classification tracks for overflow classification space during the inspection and preparation time of a departing train. Lead tracks of sufficient lengths should be provided at the outgoing end so that any doubling may be done without fouling the entering end of the classification tracks and thus interfering with hump operations.

f) Reclassification of cars in a hump yard may be economically accomplished by flat switching on the departure tracks, but departure tracks should not be installed primarily for this purpose.

g) Considerable reclassification of cars in a hump yard is an indication of an insufficient number of classification tracks.

h) The hump master's cabin, hump signal control, and other communication facilities should be located at the summit of the hump on the right hand side. (It is desirable that cars be uncoupled from the right hand side so that the forward knuckle will be open, as the impact of normal coupling will often close the rear knuckle.)

323) Hump Yards with Car Riders

a) A rider track should be provided through the classification yard independent of other yard tracks, so arranged and operated as to reduce the hazard of personal injury to car riders and to minimize the number required by facilitating their prompt return to the hump.

b) The gradients from the summit of the hump should be such that cars will run by gravity to the far end of each classification track, and the steepest of these gradients should be immediately following the summit of the hump.

c) A hump may be raised temporarily in the winter when conditions require.

d) Tracks for empty classifications should be so located in the classification yard, and the gradients leading to them should be such that empty cars moving to them will not be overtaken by loaded cars.

324) Hump Yards with Retarders—General

a) Many factors local to each situation affect efficient operation of a retarder yard, so that each terminal must be studied independently to produce a proper design.

b) The classification tracks generally should be divided into groups, each group served by a sub- or group lead. The hump lead and the group leads should be designed to direct the cars quickly into diverging routes with a minimum distance between the summit of the hump and most distant clearance point. Lap switches and short turnouts are of desirable assistance in obtaining this minimum.

c) Retarder towers should be located so that operators will have a clear view at all times of the cars they are controlling.

d) The control of switches and retarders should be distributed among the towers so that the work will be evenly apportioned among the operators, so far as practicable.

e) Loud speaker telephone circuits between the hump and each retarder tower are essential.

f) Pneumatic tubes between the general yard office and strategic points will reduce time in handling waybills, inspection lists, etc.

g) Teletype machines or pneumatic tubes between the yard office, the hump cabin and retarder towers, will permit handling cut lists promptly.

h) Adequate yard lighting is always desirable, but is particularly necessary for the safe operation of a hump yard with retarders. It is essential that the visibility be particularly good in the retarder zone. Supplementary lights, if necessary, should be provided so that the retarder operators may check the numbers and initials of cars passing their towers.

i) Hot oil applied to the car wheel journals during cold weather will decrease journal box resistance, thus minimizing the difference between winter and summer car resistances. Hose outlets with drip connections should be located on each side of the hump track two or three car lengths in advance of the summit of the hump. The oil should be applied to the journals under pressure and at a temperature of not less than 130 degrees Fahrenheit.

j) Flange oilers have a marked effect on car resistance, both in lowering the total resistance encountered and in decreasing the spread between resistances in the action of individual cars. Moreover, their use introduces a valuable element of flexibility available to overcome in part the higher resistances encountered in winter weather.

325) Hump Yards with Retarders—Design of Gradients

a) Two basic operating conditions should be considered in designing the gradients of a classification yard:

(1) The heavy easy-rolling car moving under the most favorable running conditions (hot weather, following wind, etc.).

(2) The light hard-rolling car moving under the least favorable running conditions (cold weather, adverse winds, etc.).

b) Sufficient difference in elevation, or drop, must be provided from the summit of the hump to the clearance point of any classification track to ensure that the hard-rolling car under adverse conditions will roll at least into clear on its classification track; however, it is fundamental that cars shall not accelerate unduly after leaving the last retarder, if damaging impacts are to be avoided. Hence the gradients that should be provided below the last retarder must be such as will result in little, if any, acceleration of the easy-rolling car under favorable conditions. Thus, the drop from the summit of the hump to the end of the last retarder should be "'A' minus 'B'", where

'A' is the drop required between the summit of the hump and clearance point, based on the hard-rolling car under adverse conditions, and

'B' is the drop required from the end of the last retarder to clearance point, based on the easy-rolling car under favorable conditions.

This drop—between the summit of the hump and the last retarder—should be so apportioned that:

(1) The hump gradients will quickly separate the cars or cuts to provide the spacing necessary for the free throwing of switches.

(2) The gradients through the last retarder are sufficient to start an average rolling car which has been stopped in the last retarder.

c) An analytical method of designing gradients for a hump and classification yard with retarders is shown in detail, with typical example, on pages 129–133, Vol. 33, 1932 Proc. Two graphic methods applying to this problem are shown in detail on pages 177–189, Vol. 34, 1933 Proc.

d) Where a scale or scales are installed on the hump, and/or two tracks are built over the hump with double crossovers, the distance from the summit of the hump to the clearance points of the classification tracks will be materially increased. This will result in increased height of the summit of the hump to provide enough drop for the light hard-rolling cars under adverse conditions, and this will necessitate additional retarding capacity to provide for the heavy easy-rolling cars under favorable conditions. The increased height of hump will also mean increase in cost of constructing the yard and in cost of operation.

33) Yards—Receiving, Classification, Departure, etc.

331) Receiving Tracks

a) The number of receiving tracks should be such that there will be one available whenever an arriving train offers to enter the yard.

b) The length of receiving tracks should be such that each will accommodate a complete train, including assisting locomotive where used.

c) The gradient of receiving tracks, if adverse to the forward movement of a train, should be at least 20 per cent less than the ruling gradient encountered by that train during its road trip.

332) Classification Tracks

a) The number of classification tracks should be such that there will be at least one available for each important classification.

b) The length of classification tracks should be such that each will normally hold all accumulated cars of the assigned classification until they are to be moved off the classification track under normal operation.

c) Where cars of single classifications accumulate rapidly enough to permit of forwarding them in whole trains, the classification tracks may be used as departure tracks for such business, with their lengths determined accordingly.

333) Departure Tracks

a) The number of departure tracks should be such that there will be one available for assembling a departing train whenever necessary.

b) The length of departure tracks should be such that each will accommodate a complete train, including assisting locomotives where used.

c) The gradient of departure tracks, if adverse to the forward movement of a train, should be at least 20 per cent less than the ruling gradient to be encountered by that train during its road trip.

d) Compressed air at suitable pressure should be piped along the departure tracks, and sufficient outlets should be provided to permit of testing the air brake equipment on the cars of all departing trains.

334) Bad Order and Repair Tracks

a) Bad order tracks should be provided as required to accommodate the bad order classification and should be so located as to be convenient of access, both for setting out bad order cars and for moving these cars to the repair tracks.

b) The location of the repair tracks should be such that the connection from the bad order tracks will be as direct and as simple in alinement as practicable, that switching the repair tracks will not interfere with other work going on in the yard, and that repaired cars may readily be returned to the receiving, classification or departure tracks as required.

c) The capacity of the individual repair tracks should not exceed 15 cars each, and in computing this capacity 55 feet should be allowed for each car.

d) The spacing of repair tracks should be alternately 16 feet and 24 feet center to center, and they should preferably be connected at both ends.

e) A material supply track should be placed between the repair tracks which are spaced 24 feet center to center.

f) A locomotive crane is usually economical for use in transferring freight between open top cars when the manual labor otherwise required is the equivalent of the constant daily service of six men. The intermittent use of a locomotive crane, when the machine may be economically employed at other times, is usually justified when it replaces similar intermittent service of six men.

335) Miscellaneous Tracks

a) Caboose tracks should be so located that cabooses can be placed on and removed from them in order of their arrival, and should preferably be so constructed that cabooses can be dropped by gravity onto the rear of trains made up for departure.

b) Drill tracks should be so located that movements on them will cause a minimum of interference with other work being done in the yard and with road trains pulling into or out of the yard, and that an engineman working on the drill track will have a clear view of the switchmen working along the ladder track.

c) Ice house, stock pens, LCL transfer, etc., should be so located that cars may be placed with minimum delay after arrival and be readily accessible for switching or placement in outbound trains.

d) Lead tracks somewhat longer than a maximum train length, or freight main tracks extending to or beyond the first telegraph office outside of the yard, in either or both directions, should be provided as required.

e) Running tracks should be provided as required to permit free movement from one position in the yard to another and between the yard and the locomotive terminal, with a minimum of interference with other work being done in the yard.

f) Scale tracks should be so located that weigh cars can be weighed with a minimum delay to yard operation. A track parallel to the scale track should be provided for non-weigh traffic.

34) LCL Freight Facilities

341) Freight Transfer Stations

a) A freight transfer station should be provided where it is desired to consolidate LCL freight from a greater into a lesser number of cars, or vice versa, or where it is desired to transfer package freight from foreign line cars into home line cars for forwarding to destination.

b) The transfer platform, for hand trucking, should be not more than 24 feet wide, should be covered, and should have a pair of tracks on each side of it.

342) Freight Houses—General

a) The ultimate size of a freight house should be determined in advance from consideration of the average amount of traffic to be handled through it in the first instance, the variation of peak from average requirements, and the probable growth of requirements during the period in which the cost of the structure can be amortized.

b) The initial size should be determined by immediate needs with provision for increases to the ultimate size as required.

c) Minimum operating costs can be attained in freight houses of greater capacity by locating the house tracks between two houses connected at the bumper end of the tracks by a platform.

d) Combination inbound and outbound freight houses should be arranged with the house tracks between them, and be connected at the bumper end of the tracks by a platform.

e) The factors of design for a freight house, such as tailboard frontage, floor area, width of house, platforms, bridges and roadways, and the capacity of elevators, should be so correlated that no one factor will limit the capacity of the house.

343) Freight Houses—House Tracks

a) The capacity of the inbound house tracks should be such that not more than one change in the inbound setting of cars need be made during the daily period of freight house operation, and that this change may be made during the noon hour.

b) The capacity of the outbound house tracks should be such that the outbound setting of cars may be left undisturbed during the daily period of freight house operation.

c) Spotting cars at freight houses to permit of trucking through them is common practice, and the cost of spotting and recoupling, exclusive of all other switching, based on a switch engine and crew cost of $12.50 per hour, amounts to approximately 28 cents per car.

d) Spotting may be eliminated by providing a platform and continuous doors on the track side of the freight house, constructing platforms between each pair of house tracks, and connecting them to the freight house by a platform at the bumper end of the tracks, and, when the length of the setting is sufficient to warrant, by the installation of trucking bridges at intervals through the setting.

e) Spotting is more economical than intermediate platforms when land values exceed $6 per sq. ft.

344) Freight Houses—General Dimensions

a) Tailboard frontage has an average capacity of approximately 1.12 tons per linear foot per day, and may determine the minimum length of freight house required.

b) The gross floor area of an inbound house should be provided at the rate of approximately 130 sq. ft. per ton of daily capacity of the house.

c) The width of an outbound house where tractor trucking is to be used, should be from 50 to 60 feet.

d) The shortest length consistent with adequate tailboard frontage is the most economical for both inbound and outbound freight houses.

345) Freight Houses—Trucking and Stowing

a) The cost of tractor trucking in the freight house in dollars per ton, on the basis of an average rate of pay for labor of 51 cents per hour, can be determined approximately by the equation $C = 0.14 + 0.0183d$, in which d represents the average distance in hundred feet that freight is trucked.

b) The cost of hand trucking in the freight house in dollars per ton, on the basis of an average rate of pay for labor of 48 cents per hour, can be determined approximately by the equation $C = 0.13 + 0.06d$, in which d represents the average distance in hundred feet that freight is trucked.

c) The average trucking distance in an outbound house where freight is received uniformly along one side and distributed uniformly along the other side, is theoretically one-third the length of the house, but in practice it approximates three-tenths the length of the house.

d) Tractor trucking is more economical than hand trucking when the length of the house and tonnage handled are sufficient to warrant its use.

e) The cost of stowing, which also includes the cost of trucking the freight from the freight house or platform through the cars, in dollars per ton, on the basis of an average rate of pay of labor of 52 cents per hour, can be determined approximately by the equation $C = 0.12 + 0.0367N$, in which N represents the average number of cars in each run through which freight is trucked for stowing.

346) Freight Houses—Two-Level

a) A two-level freight house occupies less land area per ton of capacity than a one-level freight house, but the cost of construction is greater, and the building cannot be altered as readily to meet changing conditions.

b) Differences in elevation between track and street level, due to topography or grade separation, may indicate the advisability of a two-level freight house in order to eliminate teamway ramps.

c) Grade separation of tracks and highways may be secured in a two-level freight house so that there is no interference between teaming and switching movements, and so that with trucking on the track level, the length of car settings is not limited to the distance between streets.

d) Trucking costs in a properly designed two-level freight house are less than in a one-level freight house of the same capacity, but this is somewhat offset by the cost of elevating freight.

e) Stowing costs will be less in a two-level outbound freight house than in a one-level outbound freight house if the loading platform is located in the middle of the outbound setting of cars.

f) A combination inbound and outbound freight house of the two-level type is more economical than separate inbound and outbound freight houses of this type.

g) A two-level freight house is more economical than a one-level freight house when land values exceed $20 per sq. ft., but the development of air rights above the freight terminal for other than railway purposes may in such cases warrant a one-level installation.

h) A multiple-level inbound freight house may prove an economical method of securing additional storage space for freight.

347) Freight Houses—Elevators

a) The freight elevator is the principal means so far developed for the vertical transportation of freight in freight houses, though conveyors and other devices have been suggested and perhaps tried.

b) Elevator control may be either automatic or manual, but most new installations are of the push-button automatic type.

c) The number of elevators in a two-level outbound freight house (where the major longitudinal trucking is done by tractors on one level, and the minor trucking, i.e., from wagon to nearest elevator, or from nearest elevator to cars is done by hand on the other level), if they are uniformly spaced, has practically no influence on the average length of tractor trucking, but does influence the average length of hand trucking and the capacity of the house.

d) The distance between elevators which will theoretically result in minimum trucking and elevating cost in a two-level freight house operated as in item 347–c is represented by the equation

$$g = \sqrt{\frac{(Pr + E)L}{0.015\,T}}$$

in which g represents distance between elevators in hundred feet, P represents the first cost of one elevator, r represents the annual interest rate, E represents the annual cost of one elevator operator, L represents the length of house in hundred feet, and T represents the total yearly tonnage.

348) Warehouses

a) Each warehouse constitutes a problem for special analysis and study. The quantity and character of commodity to be handled, the rate of turnover, and other variables affect the problem (see pages 67–76, Vol. 23, 1922 Proc.). Under average conditions, the following relations should exist between factors of design in warehouses:

b) One elevator should be provided for each 40,000 sq. ft. of warehouse space served.

c) The shipping platform area should be 4 per cent of warehouse storage floor area.

d) There should be one car length of track siding for each 17,600 sq. ft. of warehouse storage area.

e) There should be one foot of tailboard frontage for every 1100 sq. ft. of warehouse storage area.

f) There should be 16 feet of tailboard frontage for each car length of siding.

35) Team Yards and Driveways

351) Team Yards

a) The location of a team yard should be such that it will be convenient for use by shippers and consignees, and also as convenient as possible to a freight house, so that the receipt and shipment of freight may be easily under control of the freight agent's force.

b) A crane for handling heavy freight should be provided when required.

c) A motor truck scale, with office, should be provided near the main entrance to the team yard when required.

d) Switching tracks for holding and working cars should be provided in the immediate vicinity of the team tracks and so arranged as to facilitate the switching of these tracks.

e) The spacing of tracks, where multiple team tracks are built, may be fixed by regulatory bodies, but it is recommended that the maximum distance between track centers be 13 feet.

f) The distance between track centers where the driveway is located between tracks, should be ten feet greater than the width of the driveway.

352) Freight House and Team Yard Driveways

a) Freight house and team yard driveways should be paved and maintained in good condition.

b) The maximum width of a freight house driveway should allow for trucks backed up to the freight house at right angles and leave room in front of the truck for two trucks to pass.

c) Team track driveways normally should be of sufficient width to allow the longest trucks using the driveway to stand at right angles to the car, with sufficient space remaining in front of the truck to allow another truck of maximum width to pass.

d) Except for heavy machinery, heavy rolls of paper, and similar shipments, practically all commodities handled on team tracks are adapted to side loading of trucks if the height of the truck bed above pavement surface is approximately the same as that of the car floor above pavement surface.

e) It is not advisable at the present time to recommend generally a width of team track driveway based on exclusive side loading of trucks, though the economic advantages of this method of loading from the railway's standpoint are obvious. Truck manufacturers should be encouraged in the building of trucks adapted to side loading.

f) Stub-ended driveways serving team tracks should be avoided. Where team tracks are more than 20 cars long (per single track), intermediate connecting cross drives should be provided. In large team track developments where exceptionally long tracks are provided, cross drives should be introduced so that 14 cars per track is the maximum length between any two drives.

36) Produce Terminals

361) General Type

a) Produce terminals are designed for expeditious and economical delivery of fruits, melons, vegetables, and sometimes butter, eggs and live poultry.

b) Terminals should be located and designed to handle peak business.

c) A union terminal serving the entire trade of a community is preferable.

d) The location must be convenient for dealers with easy access over wide and well improved highways and easy gradients. It should have convenient railway connections. A location adjoining a railway terminal yard is advantageous.

e) A produce terminal usually includes a team yard and buildings for display, sale and storage of produce. Any or all of the following facilities may be required:

(1) Receiving yard.
(2) Inspection and hold yard.
(3) Team yard.
(4) Buildings divided into separate stores.

(5) Buildings for display and private sale.
(6) Buildings for display and auction.
(7) Auction rooms.
(8) Office, restaurant, etc.
(9) Cold storage warehouse.
(10) Icing facilities.
(11) Bulk delivery platforms.
(12) Inspection platforms.
(13) Live poultry platforms.
(14) Ripening facilities.
(15) Reconditioning facilities.
(16) Motor truck scales.
(17) Incinerator.
(18) Farmers' market.
(19) A track system serving the yards and buildings.
(20) A system of driveways for truck movements.
(21) Communication service.
(22) Fire protection facilities.

362) Buildings

a) Ample floor space should be provided for mechanical handling from cars to warehouse floor, display of produce and assembly of various lots for delivery to trucks.

b) Column spacing should be given careful study and be as wide as possible, consistent with economic design.

c) Back-up space for trucks should be as liberal as possible.

d) Canopies should be provided to protect produce while unloading from cars and delivering to trucks.

e) Ample provision must be made for natural and artificial lighting.

f) The roof, walls and floor should be properly insulated to help control temperatures.

g) Special attention should be given to the floor material on account of the continued trucking and the commodities handled.

h) Proper drainage must be provided to insure sanitary conditions.

i) Special features should be considered, such as heating, refrigeration, air-conditioning, ripening rooms and special requirements of the dealers.

j) Space must be provided for cooperage.

k) Offices and auction rooms are usually located at one end of the building or in a second story. Auction rooms require exceptionally good lighting, ventilation and acoustic treatment. Auction rooms should have sloping floor arranged in steps for seating accommodations.

l) Restaurant space is usually required in the larger terminals.

m) Where the terminal consists of a number of individual stores, the requirements should be worked out in advance with the dealers. Elevators, platform scales, and other special facilities may be required. Consideration should be given to the proper metering of all services provided.

n) The economical width of auction and private sales buildings appears to be between 70 feet and 110 feet.

o) Shelters, properly heated and lighted, should be provided for team yard checkers.

363) Track Layout

a) The track layout should be as compact and flexible as possible, and extensive enough to take care of traffic without delay. It is governed by the number of cars handled at peak periods, the different kinds of produce received, and the average standing time until cars are released.

b) A receiving yard is sometimes desirable for receiving transfers from various roads and for assembling empties and reconsigned cars.

c) A hold and inspection yard is sometimes provided. This yard should have inspection platforms, and cars should be accessible for icing. It may be a separate yard or combined with the receiving yard.

d) Team yards should have ample standing capacity. Extremely long tracks should be avoided.

e) Track centers should be not less than 13 feet.

364) Driveways

a) Team yard driveways should be hard-surfaced and have at least 45 feet clear width between cars.

b) Driveways between buildings or between a building and a team track should have preferably a clear width of 80 feet.

365) Platforms

a) Inspection platforms should be four feet six inches to 6 feet wide, 3 feet 3 inches above top of rail, and at least 5 feet 9 inches from center line of tangent track. Platforms should be covered and lighted.

b) Platforms used exclusively for handling live poultry should be 16 feet to 20 feet wide, 3 feet 5 inches above top of rail, and at least 5 feet 9 inches from center line of tangent track. Platforms should be covered, and light and water provided. Roof supports should be located to minimize interference with handling crates. Space for crate storage and repairs is usually required. Facilities for handling live poultry business should be accessible for trucks, but located as far as possible from produce houses.

c) House platforms, when served by both highway vehicles and railway cars, should be 4 feet above top of rail and 8 feet from center line of tangent track.

d) Clearance must comply with State regulations.

366) Icing

a) All cars in team and hold yards should be accessible for icing, which is usually done by contract with local dealers. Access may be from narrow driveways or from icing platforms.

367) Garbage and Refuse Disposal

a) Cars should be thoroughly cleaned after unloading, and all refuse and garbage removed from platforms, buildings, etc. Special equipment such as sweepers, dump carts, etc., should be provided in large terminals. Garbage may be handled by city collection, by contract, or incinerated. An incinerator, if required, should be of ample capacity to handle one day's collection in six to eight hours, conveniently located, and designed to burn garbage having a high water content.

368) Miscellaneous

a) Ample drainage is essential for buildings and yards.

b) Floodlighting the entire area is desirable in addition to local lighting.

c) The entire area should be strongly and closely fenced to prevent trespass.

d) Definitely assigned entrances and exits should be provided.

e) A cold storage warehouse, if required, should have suitable track service and convenient means of communication with other buildings.

f) Adequate parking space should be provided.

g) Motor truck scales, when required, should be located at a point convenient for the drivers and near the freight office. The location should not interfere with truck movements in the driveways.

37) Grain Elevator Storage Yards and Plant Tracks

371) General

a) Track facilities to serve large grain elevators involve special yard design. Cooperation between the elevator engineer and the railway engineer is essential to the development of a satisfactory plan.

b) The location of elevator site, type and capacity of elevator, topography and local conditions will influence the arrangement of tracks.

c) When selecting the site consideration should be given to property values, possible arrangement of connections to plant tracks, local railway operating conditions, and future expansion of elevator plant and of existing railway facilities.

d) Proposed method of railway operation should be established and approved by the elevator operating company and operating officials of the railway.

372) Grain Elevators—General Types

a) There are three general types of grain elevators, viz: (1) rail to rail, (2) rail to water, and (3) water to rail. Specific plants may be combinations of these types.

373) Elevator Plant Tracks—Loading and Unloading Tracks

a) The number and capacity of unloading tracks will depend upon the type, arrangement and capacity of elevator unloading facilities, but may be limited in some cases by the space available.

b) The car capacity of the tracks above and below the loading or unloading facilities should be the same.

c) Where the car capacity of the unloading tracks on each side of the unloading facilities is equal to the normal daily unloading capacity of the elevator plant during the grain handling season, and where the car capacity of the loading tracks on each side of the loading facilities is equal to the normal daily business handled, the plant switching will be reduced to a minimum.

d) Double ended tracks will permit the continuous movement of cars in one direction and facilitate switching.

e) Spur unloading tracks may necessitate switching cars through unloading shed and over unloading facilities, requiring the use of idler cars. Locomotives should not be permitted to enter the unloading shed.

f) Adverse gradients and curvature in tracks will limit the capacity of car haul and should be avoided. An assisting gradient to and from the loading and unloading facilities should be provided. A short run-off gradient below the unloading facilities will speed up the movement of empty cars.

g) Where car unloaders are used, the track arrangement should provide for the relative increased capacity of this device. A small plant locomotive or other special car handling equipment should be considered in connection with car unloaders. Flexibility of track layout in the vicinity of car unloader, to facilitate the operation of plant locomotive, should be given special attention.

h) Loading tracks may be located on the same or opposite side of "workhouse" from unloading tracks.

i) Certain unloading tracks may be used for loading or to augment the capacity of the loading tracks.

j) Some of the auxiliary buildings, such as storeroom and dust house, may be served by the loading tracks.

374) Elevator Plant Tracks—Other Tracks

a) A running track located outside of unloading shed, should be provided where double ended tracks are installed.

b) A separate track should be provided to serve the power house.

375) Storage Yard

a) The use of a separate storage yard will require additional handling of cars; therefore careful consideration should be given to the advisability of such a yard.

b) Where the elevator is located near an existing yard and sufficient capacity is available, or can be economically provided, a separate storage yard may not be required.

c) A separate storage yard may be justified where it can be used to augment the existing yard during seasonal increases in business, or where the elevator is located some distance from the main or an auxiliary yard.

d) The capacity of the loading and/or unloading tracks may influence the necessity for a separate storage yard, as well as the capacity of such a yard.

IV—LOCOMOTIVE TERMINALS

a) In any large terminal establishment it will be a question whether or not separate locomotive terminals shall be provided for freight and passenger equipment. Convenience and expedition and low current unit costs will be the primary considerations, but all the factors of operating costs and carrying charges involved in both alternatives must be given due weight, and where only one company is involved, already having a locomotive terminal of adequate capacity or one that can be readily enlarged to meet all requirements, economy will favor continuance of such arrangement unless the layout is prohibitively remote from either the passenger station or the center of freight activities.

b) Where the establishment is joint with two or more railways, either for passenger or freight service or for both, the possibility of choice in the matter becomes important. In case only the passenger terminal is joint, it is more likely to be advisable to have it include a separate locomotive terminal and shops equipped to make all required running repairs, but there is no arbitrary rule to be applied. Even though a convenient site at reasonable cost is available in such case, all costs involved must have exhaustive analysis and be weighed against the manifestly superior expedition, simplicity of operation, and avoidance of conflicting movements of power to and from the station, to be derived under the delegated unity of control and responsibility of the terminal management.

c) In the case of a joint freight terminal, if a substantially new layout is to be substituted for several individual layouts, it may be advisable, as in the case of a joint passenger terminal, to provide a new joint freight locomotive terminal, but where existing separate facilities are merely coordinated and delegated to joint management it will generally be advisable to rely upon the existing facilities.

d) In the location of a new locomotive terminal, provision should be made for the movement of locomotives to and fro between their trains and the engine house with a minimum use of tracks used for other thorofare movements, a minimum of reverse or conflicting movements, and a minimum of light engine mileage.

V—SCALES

51—Rules for the Location, Maintenance, Operation and Testing of Railway Track Scales

- 511—*Location:* (follow paragraphs 1–4, pages 110–111, Bulletin 367–8)
- 512—*Maintenance and Operation:* (follow paragraphs 1–15, pages 111–112, Bulletin 367–8)
- 513—*Testing:* (follow paragraphs 1–3, page 112, Bulletin 367–8)
- 514—*Equipment for Testing:* (follow paragraphs 1–2, page 112, Bulletin 367–8, including table of tolerances for master scales at top of page 1032, Manual)
- 515—*Definition of a Standard Test of a Railway Track Scale:* (follow paragraphs 1–8, pages 113–115, Bulletin 367–8)
- 516—*Specifications for Railway Track Scale Test Weight Cars:* (follow paragraphs 1–14, pages 58–61, Bulletin 356)
- 517—*Maintenance and Transportation of Track Scale Test Weight Cars:* (follow Foreword and paragraphs 1–3, pages 115–117, Bulletin 367–8)
- 518—*Disposition of Obsolete Track Scales:* (follow page 117, Bulletin 367–8)

52—Specifications for the Manufacture and Installation of Four-Section Railway Track Scales: (follow pages 1008–1026, Manual)

53—Specifications for the Manufacture and Installation of Two-Section Railway Track Scales: (follow pages 1050–1067, Manual)

54—Endorsement of Specifications for the Manufacture and Installation of Light Industrial Service Railway Track Scales: (follow page 66, Bulletin 327)

55—Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-contained and Portable Scales for Railway Service: (follow pages 67–86, Bulletin 378)

56—Tolerances for Large-Capacity Automatic-Indicating Scales: (follow pages 1067–1069, Manual)

DELETIONS

The herewith proposed rearrangement and revision of the Yards and Terminals chapter of the Manual contemplates the deletion of the following items in the 1929 Manual and Supplements:

Page 960—paragraph 8
Page 962—paragraphs 21 and 22
Page 964—paragraph 38
Page 966—paragraph 56
Page 969—paragraphs 77 and 81
Page 970—paragraph 82
Pages 972–988, inclusive—diagrams
Page 992—paragraphs 13 and 14
Page 993—paragraph 16
Page 997—paragraph 11
Page 998—paragraphs 12, 13, 22 and 26
Bulletin 367–8, page 110—paragraph 28
Page 999—paragraphs 29, 30, 31 and 35
Page 1001—paragraphs 55 to 62, inclusive, including diagram entitled "Cut List"
Page 1002—paragraphs 63 to 69, inclusive
Page 1003—paragraphs 80, 81, 83 and 85
Page 1004—paragraph 90
Page 1005—paragraph 110
Bulletin 356, page 57—from beginning of paragraph reading, "The following formulae may be used - -" to bottom on page
Bulletin 356, page 58—first four paragraphs at top of page
Bulletin 378, page 67—last paragraph under heading "Other Tracks" near top of page
Page 1007—Definitions as follows:
    Scale
    Motor Truck Scale
    Built-in Scale
    Self-contained Scale
    Portable Scale
Page 1068—"Note" near top of page

Appendix B

(4) COAL TRANSFER TERMINALS

E. T. Johnston, Chairman, Sub-Committee; C. E. Armstrong, C. J. Astrue, E. J. Beugler, W. O. Boessneck, N. C. L. Brown, H. F. Burch, W. H. Giles, G. F. Hand, M. J. J. Harrison, E. M. Hastings, W. H. Hobbs, J. M. Hood, E. K. Lawrence, L. L. Lyford, C. P. McCausland, C. H. Mottier, A. E. Owen, W. B. Rudd, W. C. Sadler, C. U. Smith, E. E. R. Tratman, H. L. Vandament.

General

In the year 1934 the coal production of the United States was about 57,385,000 tons of anthracite and about 357,500,000 tons of bituminous, or a total of about 414,885,000 tons. This was about 32 per cent less than the 1929 production, the peak year of the last decade. In the transportation of coal from mine to consumer, a large amount must be transshipped. The principal transfers are between rail and water as outlined below. Some of the fundamental considerations for transfer are low cost of handling, speed of operation, reduction of breakage and facilities for weighing and for classifying various grades of coal. Transfer is made by gravity wherever conditions are favorable; otherwise by a great variety of mechanical equipment, such as car dumpers, conveyors, grab buckets and transfer bridges. Some present installations are illustrated on the plans in this report and the methods of operation are briefly described.

Cars, loaded and empty, are handled by gravity as much as possible and in some installations car retarders are employed to control the movement of cars. Thawing houses (in which coal frozen in the cars is thawed by steam or hot air) or other means of thawing coal, such as the use of steam or hot air lines and spear points, are necessary in cold climates. Ample storage (on cars, bins or ground storage) and classification facilities are provided at or near the transfer. Facilities constructed adjacent to waterways have dock or pier lengths adequate for berthing the largest type of coal vessel in operation at the particular port, with consideration to possible increase in length of vessels, and are readily accessible by channels of adequate depth and width. Primary considerations in the selection of type and size of plants are tonnage handled per day, type of vessels and period in which a vessel must be either loaded or unloaded on account of demurrage charges or charter rates. The plants described in this report are the larger and more elaborately equipped terminals. There are, of course, a great number of small plants and the design of these is based on the same fundamentals as the design of large terminals. There are numerous references of installations of various types in the bibliography of the Yards and Terminals Committee report of last year and there are additional references in the report of the current year.

CLASSIFICATION OF TRANSFER TO AND FROM RAIL

(A) Mine to Rail

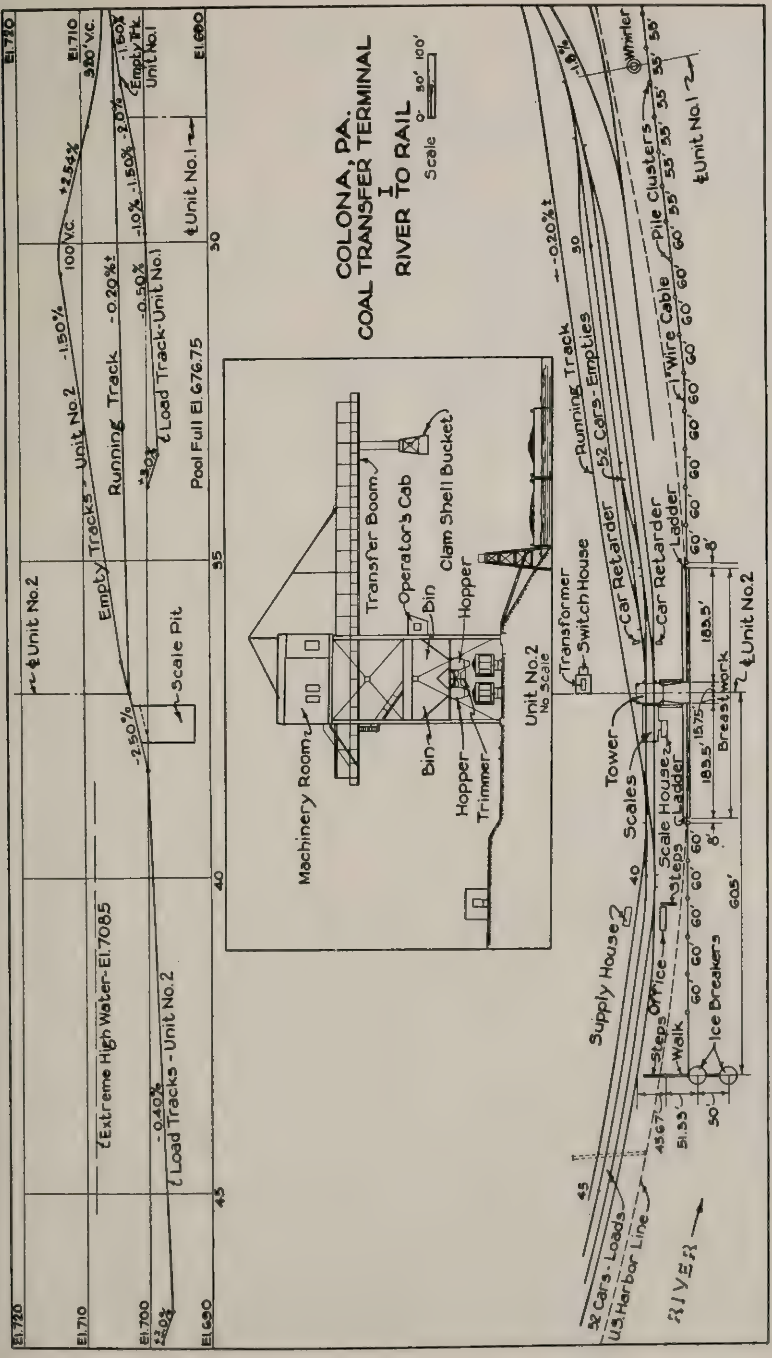
An important requirement is adequate trackage for empty and loaded cars, depending on maximum output of the mine. The number and arrangement of tracks varies depending partly upon whether the coal is shipped as run-of-mine, or is screened and sized in the tipple for shipment in various sizes and grades. Loading and shifting is usually done by mine organizations. Variable provisions are made for weighing the loaded and empty cars.

(B) River

1. General.—In many instances there is a very considerable variation in water level to be taken into consideration. Receiving tracks are conveniently located with respect to either a longitudinal wharf or a jetty type of pier. Track and equipment capacities are determined by the volume of traffic and the expedition required. Boat haul is provided in some cases.

2. River to Rail.—Mechanical equipment is necessary to transfer coal economically from river barges to railroad cars. In a modern installation, shown on plan entitled "River to Rail", coal is handled from river barges by a 10-yard, 8-ton clamshell bucket and transfer boom to two 75-ton hoppers equipped with trimming chutes. These hoppers serve cars on two tracks directly beneath them. Machinery is all housed in a room at the top of the tower. One operator handles all operations, including boat haul, except the loading of cars. Empties move by gravity, controlled by cable-type car retarders, to the loading point and after loading are released to travel by gravity over two 200-ton track scales and thence to the load yard. Unit No. 1, shown on the plan, is a supplementary unit consisting of an electrically operated whirler crane with a 75-ft. boom and a 3.5-cu. yd. bucket. Hourly capacity of Unit No. 1 is 150 to 200 tons and of Unit No. 2 about 500 tons. Two barge shifters are provided.

3. Rail to River.—Tracks with bins and chutes and/or mechanical handling equipment are used for this kind of transfer. At the plant shown on plan entitled "Rail to River", coal is dumped from hopper bottom cars to a belt conveyor, operating over a bridge to a tower in the river, where it is dumped down a chute into the barges. Loaded cars are pushed up an incline to a tilting platform, where the car coupler is engaged by a


COLONA, PA.
COAL TRANSFER TERMINAL
I
RIVER TO RAIL
Scale 0' 50' 100'
El. 720
El. 710
El. 700
El. 690
El. 680
El. 710
320' V.C.
100' V.C.
+2.54%
-1.50%
Unit No. 2
Empty Tracks - Unit No. 2
Running Track -0.20%±
-2.50%
-0.40%
-1.0% -1.50% -2.0%
-1.60%
Empty Trk. Unit No. 1
-0.50%
-0.50%
+3.0%
+2.0%
℄ Load Track - Unit No. 1
℄ Load Tracks - Unit No. 2
℄ Unit No. 2
℄ Unit No. 1
Scale Pit
℄ Extreme High Water - El. 708.5
Pool Full El. 676.75
30
35
40
45
Machinery Room
Transfer Boom
Operator's Cab
Clam Shell Bucket
Bin
Hopper
Bin
Hopper
Trimmer
Unit No. 2
No Scale
Transformer
Switch House
-0.20%±
-1.8%
Running Track
52 Cars - Empties
Car Retarder
Car Retarder
Ladder
Wire Cable
Pile Clusters
Whirler
℄ Unit No. 1
55' 55' 55' 55' 55' 55'
60' 60' 60' 60' 60' 60' 60' 60' 60'
8'
183.5'
183.5'
15.75'
Breast work
℄ Unit No. 2
Tower
Scales
Scale House
Ladder
Steps
Supply House
Office
Steps
Walk
60' 60' 60' 60' 60' 60'
8'
605'
Ice Breakers
45.67'
51.33'
50'
52 Cars - Loads
U.S. Harbor Line
RIVER

coupler on a car spotter, having a travel of 7-ft. for spotting cars of different lengths. The platform is then raised to a horizontal position, the car spotted and dumped and the platform is then tilted to its normal gradient of 2.5 per cent. The car is then uncoupled and returns by gravity to the empty yard. A considerable variation in water levels had to be taken into consideration in this design. Hourly capacity is about 750 tons.

(C) Lake

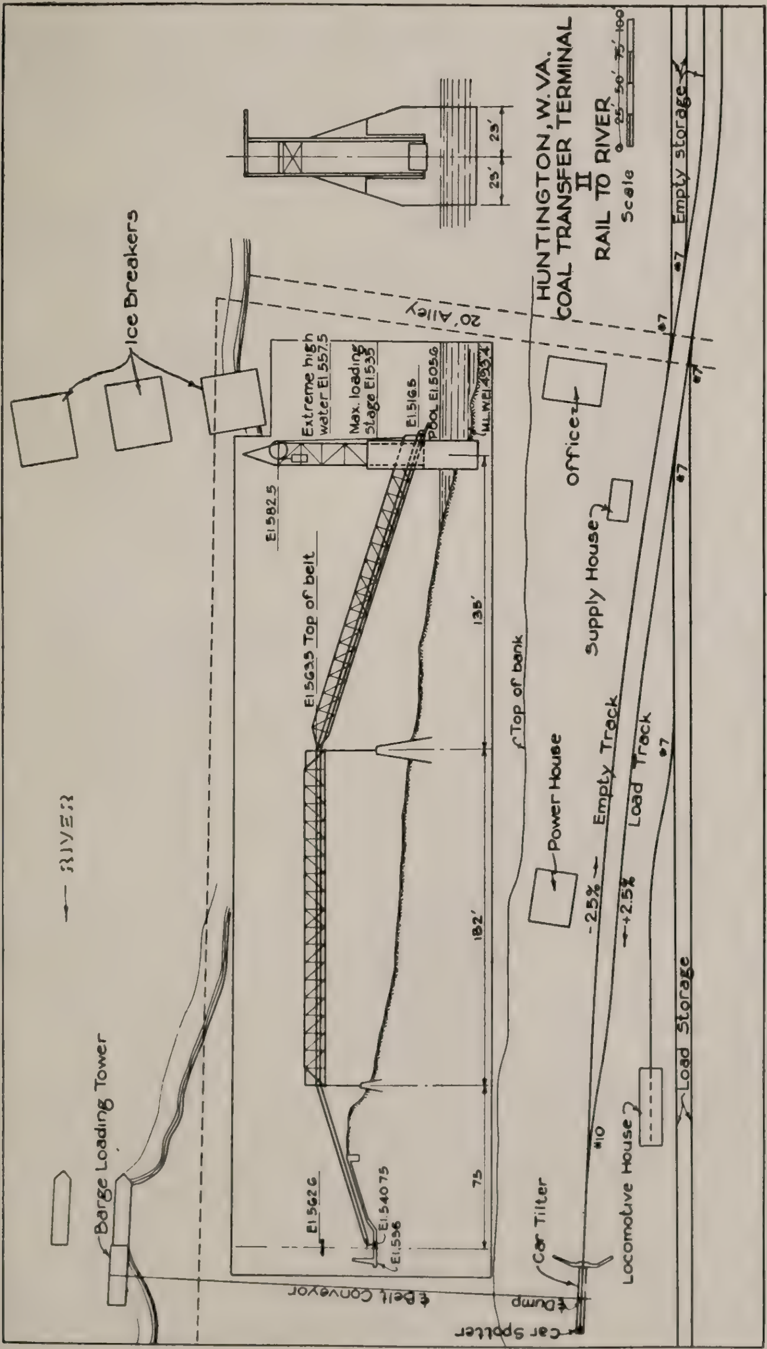
This section covers transfer from rail to vessels and from lake vessels to rail, with possibly an intermediate movement to storage in either case. Due to the volume of this business and the restricted season for navigation on the Great Lakes, facilities at lake ports are usually large and elaborate.

Self-Unloader Vessels.—In the transportation of coal on the Great Lakes, a special feature is the use of self-unloader vessels, which are independent of shore equipment and can therefore discharge the cargo at any port and any dock which the vessels can reach. The average of annual Lake shipments for the past five years has been about 32,000,000 tons of bituminous coal, with a maximum of 38,000,000 tons in 1929. Figures are not available as to the amount or proportion of the tonnage handled on self-unloader vessels, but their use is said to be increasing in favor.

There are about 30 such vessels in service (exclusive of those handling only sand and gravel). They range from 244 ft. to 615 ft. in length and from 2,400 to 10,000 tons gross register. Few, if any, are used for coal exclusively; usually they handle coal, coke, iron, ore, broken stone or even bulk cement, as business requires. They operate to and from any ports where shipments offer, on individual contracts, delivering to consignees whose docks have no unloading machinery.

In general, the hull forms two longitudinal hoppers, with loading gates, beneath which run belt conveyors or large scrapers delivering to an inclined conveyor of the flight or bucket type near the bow. This latter conveyor extends some 40 ft. above the deck and delivers to a hopper with chute feeding a belt conveyor on a pivoted boom of truss construction. The booms range from 65 ft. to 200 ft. in length. The boom can be swung horizontally through a wide range of angles on either side of the vessel for convenience in delivering the coal on the dock or storage yard.

1. Rail to Lake.—The more important rail to lake coal terminals on the lower lakes are equipped with car dumpers and other incidental facilities for prompt and inexpensive delivery of large quantities of coal to lake vessels. Track arrangement of the dock and storage capacity both for loaded and empty cars require careful study as the capacity of the plant is largely dependent on the method and dispatch of feeding cars to the dumper. Plan entitled "Rail to Lake" illustrates a modern plant of this nature. Loaded cars travel by gravity from the load yard to a mule or barney pit at the foot of the incline to the north dumper. The car is then shoved to the platen of the north dumper by a cable operated barney car running on a narrow-gage track between the rails of the standard gage track on the incline. On the platen the car is engaged by clamps which hold it firmly in position while being unloaded. The platen and car are then elevated and the car slowly rotated so as to dump its contents into a large pan from which the coal is discharged into the vessel through a telescopic chute. After unloading, the platen with empty car is lowered to normal position and the next loaded car entering the platen shoves the empty from the platen. The empty car runs down a gravity incline and up a kickback track; thence, reversing its direction, through a spring switch at the foot of the kickback, to the empty return track and over this track by gravity to the empty yard. The operation of the south dumper is similar with two important exceptions:


HUNTINGTON, W. VA.
COAL TRANSFER TERMINAL
II
RAIL TO RIVER
Scale
0 25' 50' 75' 100'
RIVER
Ice Breakers
Barge Loading Tower
El. 562.6
El. 540.75
El. 536
℄ Belt Conveyor
Car Spotter
℄ Dump
Car Tilter
Locomotive House
75
182'
135'
El. 563.5 Top of belt
El. 582.5
Extreme high water El. 557.5
Max. loading stage El. 535
El. 516.5
Pool El. 505.6
Lt. W. El. 493.4
Top of bank
Power House
Supply House
Office
20' Alley
-2.5%
+2.5%
Empty Track
Load Track
#10
#7
Load Storage
Empty storage
25'
25'

(a) Cars in the load yard are pushed to the foot of the incline and spotted over the barney pit by electric car pushers using a pusher arm which operates laterally through the body of the pusher. The tracks of the load yard are on alternate 16 ft. and 13 ft. centers, the electric pushers operating on narrow-gage tracks centered in the 16 ft. spaces.

(b) Empty movements from the car dumper platen to the empty yard are controlled by car retarders, eliminating car riders.

The hourly combined capacity of both units is about 100 cars.

Numerous auxiliary attachments are used to minimize breakage, such as car covers controlling flow of coal from car into the pan, retarders of various description and the control gate attached to the end of the telescopic chute for control of flow of coal from the chute into the vessel, the last-named being perhaps the most outstanding. Trimming devices are employed for trimming cargo in the hold.

Analysis of the profiles of ten car dumper plants shows the following gradients:

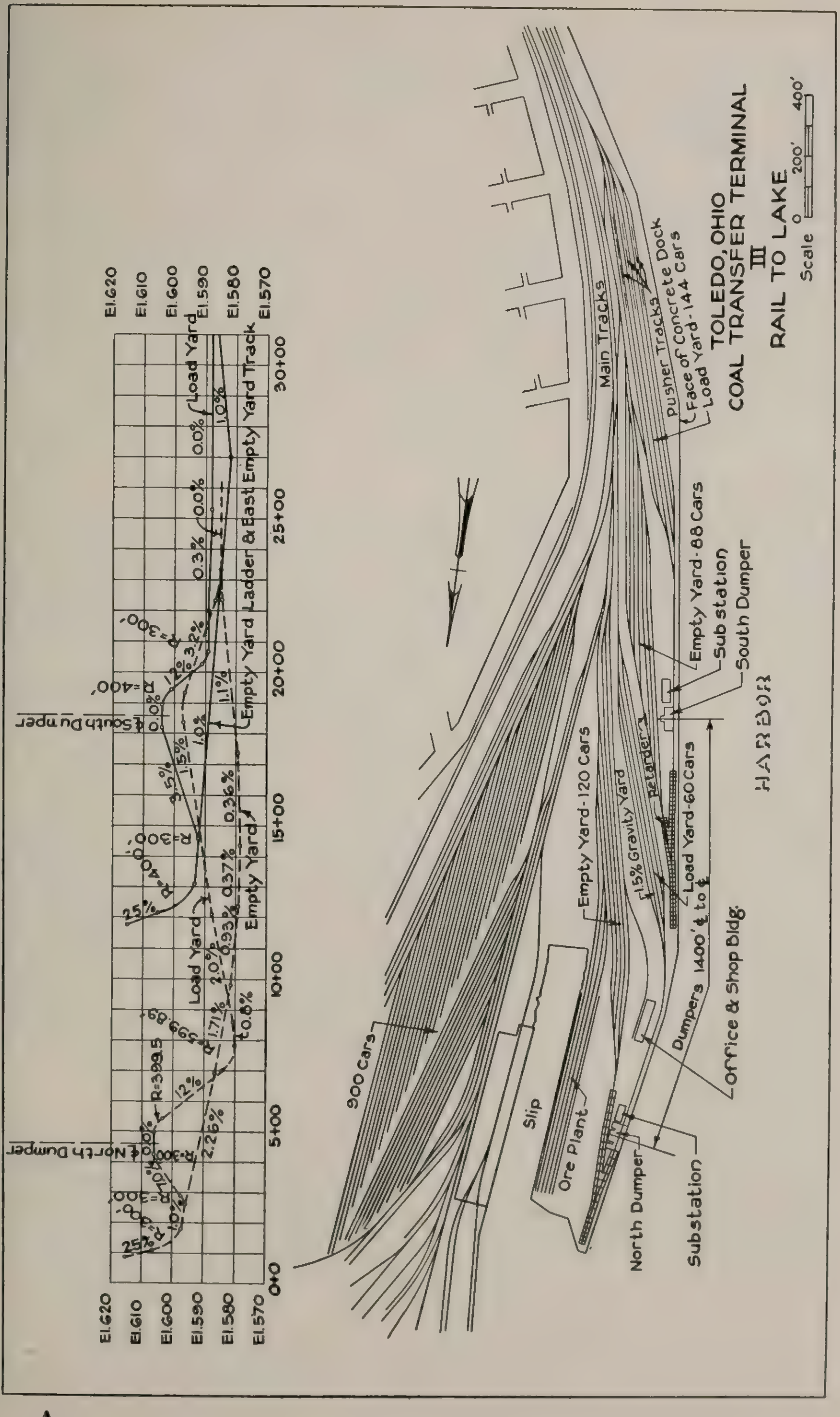
	Minimum	*Maximum*	*Average*
Receiving yard to mule pit	— 0.3%	— 2.0%	— 1.5%
Mule pit to dumper	+ 10.5%	+ 15.0%	+ 12.0%
Dumper to foot of incline	— 2.0%	— 11.0%	— 7.0%
Kickback	+ 18.0%	+ 33.0%	+ 25.0%
Foot of kickback to light yard	— 1.0%	— 3.5%	— 1.5%
Over scales			— 1.0%

Gradients are given in the direction of travel. Vertical curves are usually of as short a radius as will permit safe operation of uncoupled cars.

2. Lake to Rail.—Coal is loaded at lower lake ports in bulk cargo vessels. These come across the lakes during the navigation season, which is roughly from May 1st to December 1st. The coal is received in various forms, typical sizes being Block, Egg, Mine Run and Screenings. The coal is taken from vessels by mechanical equipment and delivered directly to cars or to storage for subsequent reclamation and loading on cars. In the latter case, facilities for classifying the different varieties and grades are required and precautions are taken to prevent combustion of the stored coal. A typical installation on the upper lakes with modern equipment is shown on plan entitled "Lake to Rail" and is described as follows:

The electrically-operated coal-handling bridge has an overall span of 490 ft. when the apron is extended over the river for vessel unloading. The bridge trolley is equipped with a 10-ton bucket capable of discharging 600 tons per hour in free digging. It is also equipped with a "clean-up" bucket, designed when closed to pass through boat hatches but opening up to a 24-ft. spread inside the vessel hold. In actual practice, including cleanup, a 10,000-ton cargo can be unloaded in 24 hours. The 10-ton bucket is first used for unloading the bulk of the cargo and unloading is completed by means of the "clean-up" bucket.

Attached to the coal-handling bridge is a screening plant with a capacity of 300 tons per hour and equal to the most up-to-date coal tipple. The bridge bucket picks up the storage coal and deposits it in a bridge hopper having a capacity of 100 tons. From there it is fed to the block screens. The block coal is conveyed to cars or into truck loading hoppers. Coal that passes through the block screen is elevated by means of a bucket conveyor to the top of the screening plant, where it is screened into various sizes such as Egg, Stove, Nut and Screenings, etc. These sized coals drop into storage hoppers in the screening plant, each capable of holding a carload or more. The screens are of most modern type of short lip shaker screens, 6 ft. wide and over 20 ft. long. They are interchangeable and practically any commercial size of coal can be screened out, from ½-inch Slack to 6-inch Block.



TOLEDO, OHIO
COAL TRANSFER TERMINAL
III
RAIL TO LAKE

After the coal is ready for loading, it is passed over an electric vibrator to remove any small material due to breakage in going through the hoppers, and is loaded into open cars by means of a boom loader, which deposits the coal without breakage. Box cars are mechanically loaded by means of a box-car loader. This machine has variable speeds and handles the coal with a minimum of breakage, placing it in the ends of the cars.

Coal is conveyed from the screening plant by means of a conveyor to the overhead hoppers for loading trucks. These hoppers are of steel, and each group has four separate 110-ton hoppers for the different sizes of coal. The entire space not under the bridge is paved with concrete, and trucks drive along one side of the hoppers, pull underneath for loading and out on the other side, resulting in one-way traffic and speedy movement. The coal is again rescreened by electric vibrator or lip screens before it goes into the trucks. In addition, there are open storage ground bins for carrying certain slower moving sizes. Coals from these bins are loaded by conveyors.

A complete line of coals for industrial and domestic use is handled across this dock.

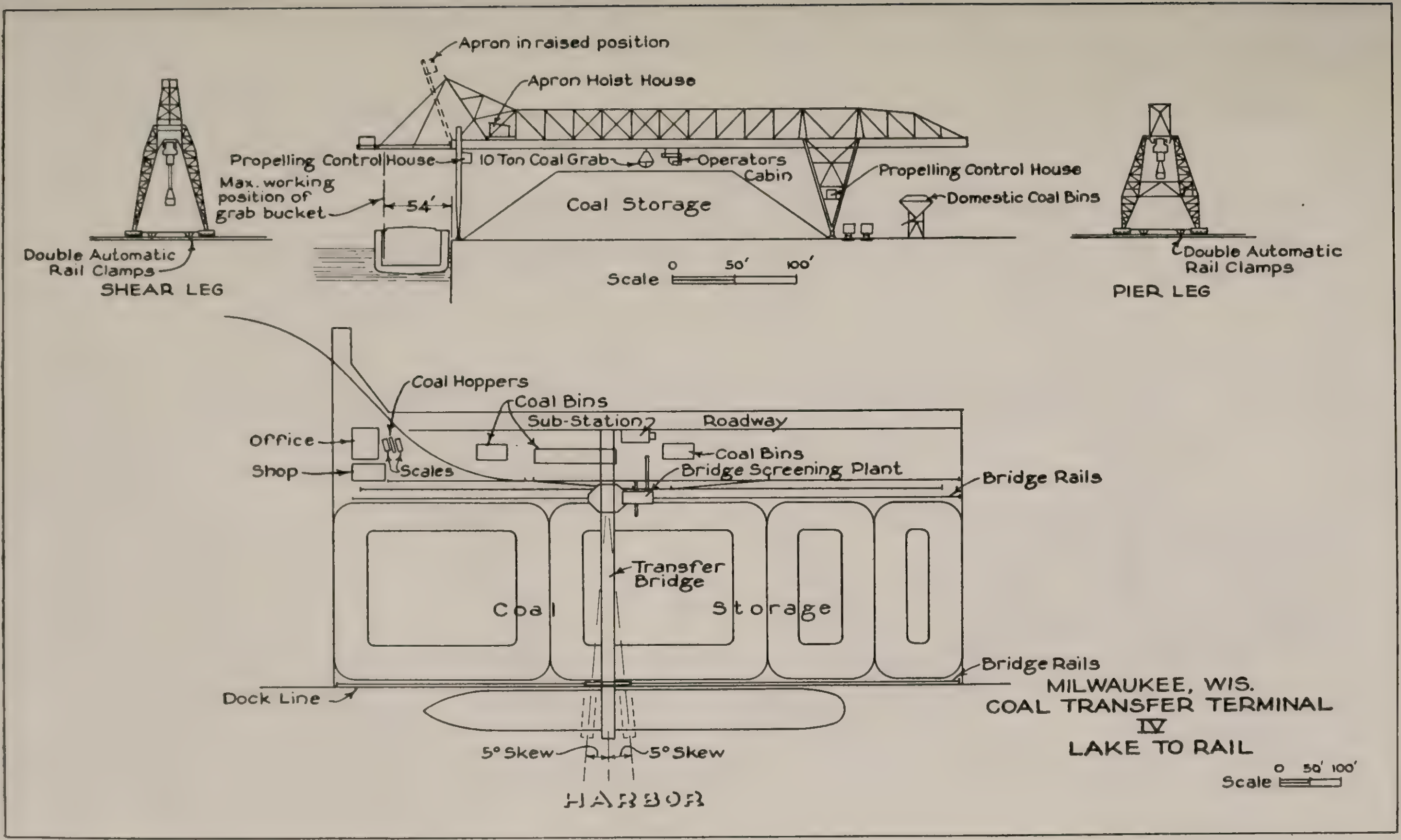
(D) Tidewater

1. Rail to Tidewater.—These facilities handle coal to export and coastwise shipping and/or to barges for local harbor deliveries. Expedition is necessary with the high demurrage charges for vessels and this requires the most improved installations as regards trackage and handling equipment. Large car storage and classification yards are required at or near the transfer point. A modern installation is shown on plan entitled "Rail to Tidewater". In general, this operation is similar to that described under "Rail to Lake", except that one unit does not elevate the platen and car but discharges the coal into a hopper, from which it is conveyed by belt conveyor to a loading boom equipped with telescopic chute and trimmer for handling coal into vessels. Total hourly capacity is about 5,000 tons. Other installations employ belt conveyors or electric cars to convey the coal either to movable towers or to elevated bins.

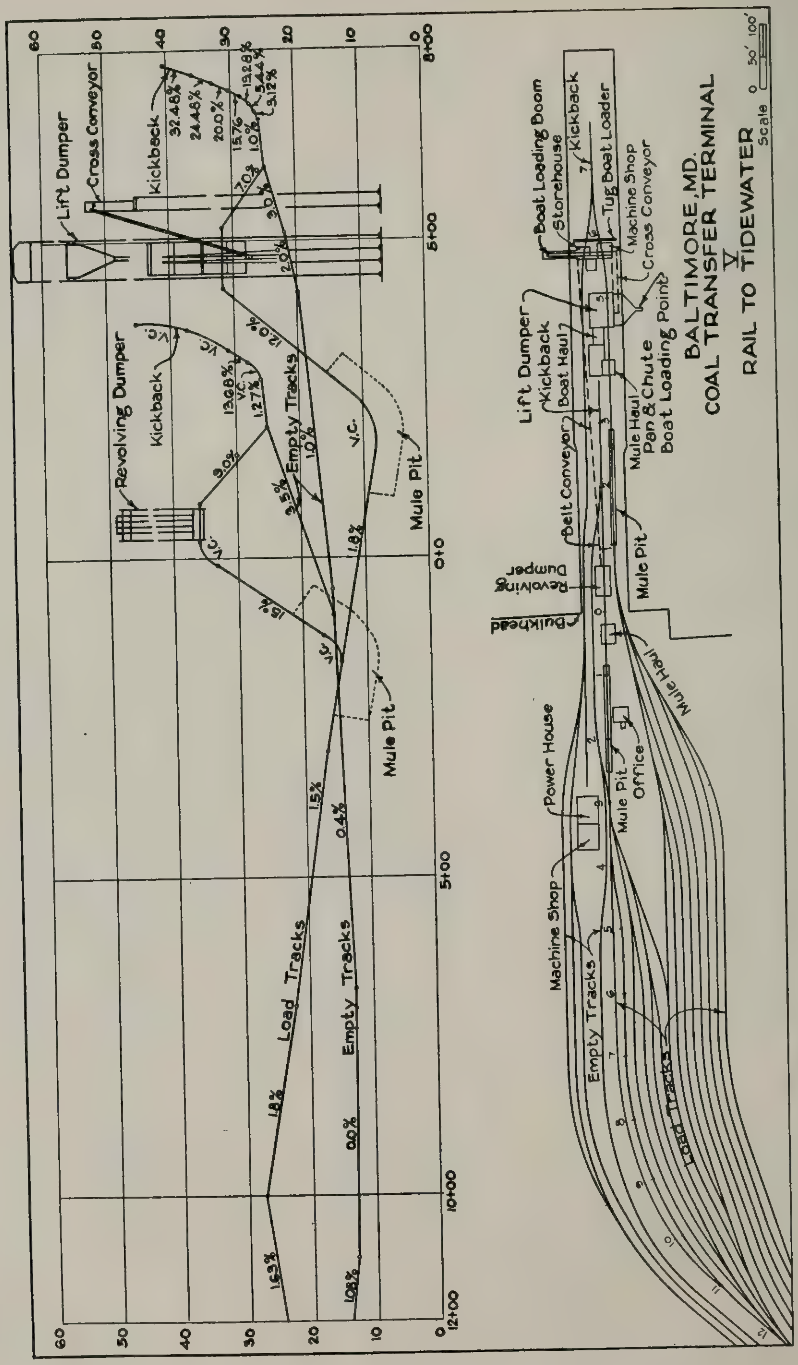
2. Tidewater to Rail.—These plants usually combine storage, truck and rail delivery. At the plant illustrated on plan entitled "Tidewater to Rail" there are five movable self-propelling unloading towers with 6,000-lb. buckets and one with 3,000-lb. bucket. Hourly unloading capacity is about 1,200 tons for the six towers. Each tower is equipped with a steam-operated car puller. As coal is removed from vessels by the buckets it is lowered into 60-ton hoppers in the towers, and thence discharged through chutes directly to cars or by a belt conveyor to a cushion pile back of the towers. From the cushion pile coal is handled for storage and later for reclamation by a 440-ft. self-propelled traveling bridge with grab bucket. Coal is thus handled from the stock pile to a 60-ton hopper which serves two railroad tracks. The hopper and coal pockets at the right are to serve trucks.

(E) Storage

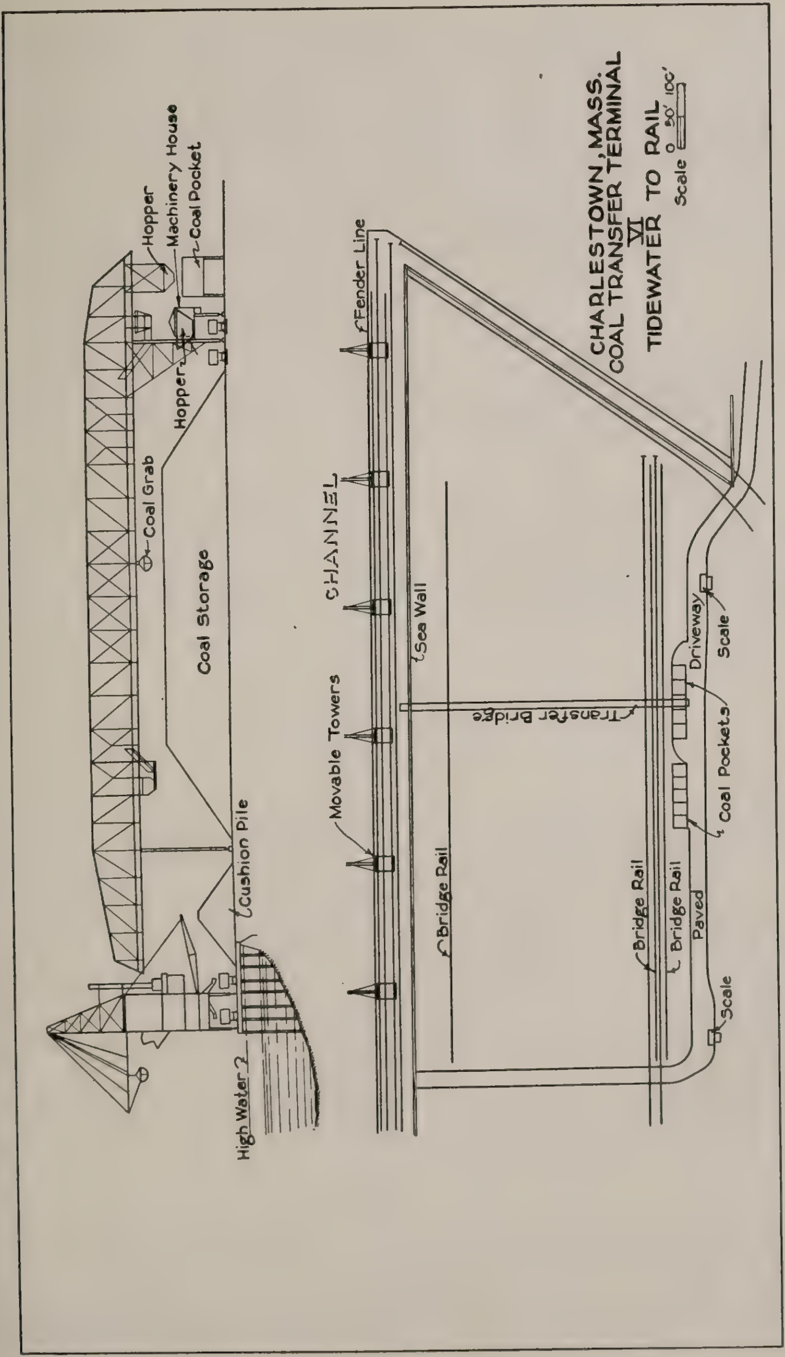
These facilities are usually privately owned and are required at most large industrial plants using coal and at coal yards. However, there are a number of large railroad storage yards used for stocking company coal, with equipment for unloading, stocking, reclaiming and reloading on cars. The track layout varies with the type of coal handling equipment.



MILWAUKEE, WIS.
COAL TRANSFER TERMINAL
IV
LAKE TO RAIL



BALTIMORE, MD.
COAL TRANSFER TERMINAL
V
RAIL TO TIDEWATER



CHARLESTOWN, MASS.
COAL TRANSFER TERMINAL
VI
TIDEWATER TO RAIL

Appendix C

(5) SCALES USED IN RAILWAY SERVICE

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Since the establishment of specifications for railway track scales began some twenty or more years ago, an accretion of requirement upon requirement to the basic specifications has occurred. The present interest in bringing the Manual up to date and into suitable form for republication has led your Committee to revise, condense and bring up to date the various codes of specifications for four-section railway track scales. A general specification covering all such scales is therefore herewith submitted, with the recommendation that it be approved as Manual material and substituted for present Manual material under the same title.

In addition to being designed to replace present Manual material, the specification now submitted is designed to replace also the following specifications which are in existence at the present time:

(1) Specifications for Track Scales for Weighing Grain (adopted by the ARA, 1920, and issued by the ARA in Grain Circular No. 1 pursuant to recommendation of the Interstate Commerce Commission in its Docket 9009 (56, I.C.C., 347)).

(2) Specifications for the Manufacture and Installation of Light Industrial Service Railway Track Scales (endorsed by the AREA, subject to certain restrictions, 1930 (page 66, Bulletin 327, July, 1930)).

SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF FOUR-SECTION, KNIFE-EDGE RAILWAY TRACK SCALES

INTRODUCTION

These specifications are intended to apply to railway track scales for weighing cars in interchange service. They replace similar specifications adopted in 1920, and are intended to include also track scales covered by other codes of specifications, viz.: "Railway Track Scales used for Weighing Grain", 56, I.C.C., 347 (Docket 9009, Claims for Loss and Damage to Grain, decided January 18, 1920), and "Railway Track Scales for Light Industrial Service", AREA Proc., Vol. 31, page 792. They do not apply to scales originally installed before 1920, except that reinstallation of such scales should be governed as nearly as practicable by the provisions of these specifications relating to the installation of new scales. They are intended to secure reasonable uniformity in scales for similar service, without preventing improvement in types of scales or in scale parts. For special cases which are not covered in these specifications, the material, workmanship, and other qualities should be at least equal to those required herein, and the principles herein set forth should be followed so far as they apply.

The prospective purchaser of a track scale should stipulate a sectional capacity which, in conjunction with the required length, defines a scale of sufficient capacity to meet the maximal service requirements, together with such other information as will secure complete and uniform proposals.

1. CAPACITY

101) **Sectional Capacity Defined.**—The sectional capacity of a scale is the greatest live load which may be divided equally on the load pivots of a section without producing stresses in any member in excess of those specified in Section 3.

102) **Sectional Capacities Standardized.**—The rated sectional capacity of a railway track scale shall be 50, 60, 75, 100 or greater than 100 tons. The rated sectional capacity shall in no case exceed the actual sectional capacity as defined in Section 101.

103) Scale Capacity Defined.—The capacity of a railway track scale is the maximal live load it will support without stresses in excess of those specified in Section 3 being developed. The loading assumptions shall be:

a) For scales of a sectional capacity of 100 tons or less, coupled cars having 12 ft. center to center of adjacent end trucks, trucks under each car 22 ft. center to center, and truck axles 5 ft. 6 in. center to center.

b) For scales of a sectional capacity of greater than 100 tons, a series of axle loads as stipulated by Cooper's E–60 or E–70 locomotive loading diagrams.

104) Maximal Live Loads for Standard Sectional Capacities and Scale Lengths.—Table 1 shows scale capacities for different scale lengths and the standardized sectional capacities, expressed in terms of:

a) Coupled representative cars.
b) Coupled Class GT gondolas.
c) Cooper's locomotive loadings.

105) Nominal Capacity Defined and Limited.—The nominal capacity of a scale is the greatest weight indication obtainable by use of all the reading elements in combination, fractional beams totaling two per cent or less of the remaining elements being neglected. The nominal capacity of a track scale shall not exceed twice the rated sectional capacity.

TABLE 1

CAPACITIES OF FOUR-SECTION RAILWAY TRACK SCALES
(Loads given in thousands of pounds)

Length of Scale (ft.)	*Length of Span (ft.)*	*Maximum Car Loads†*		*Cooper's* Locomotive Class*
		Representative Car	*Class GT Gondola*	
50 tons sectional capacity; main load pivot reaction 50,000 lb.; dead load neglected.				
42	14	175.0		E–38
46	15.33	164.3	209.0*	E–36
50	16.67	156.2	192.2	E–34
60 tons sectional capacity; main load pivot reaction, 60,000 lb.; dead load neglected.				
42	14	210.0		E–46
46	15.33	197.1	250.9*	E–43
50	16.67	187.5	230.8	E–41
56	18.67	176.8	210.0	E–39
60	20	171.4	200.0	E–37
66	22	163.0	188.5	E–34
72	24	155.6	180.0	E–32
75 tons sectional capacity; main load pivot reaction, 75,000 lb.; dead load neglected.				
42	14	262.5		E–58
46	15.33	246.4	313.7*	E–54
50	16.67	234.4	288.5	E–51
56	18.67	221.0	262.6	E–48
60	20	214.2	250.1	E–45
66	22	206.2	235.7	E–43
72	24	194.6	225.0	E–41
100 tons sectional capacity; main load pivot reaction, 100,000 lb.; dead load neglected.				
42	14	350.0		E–77
46	15.33	328.6	418.2*	E–72
50	16.67	312.5	384.6	E–69
56	18.67	294.7	350.0	E–64
60	20	285.7	333.4	E–61
66	22	275.0	314.3	E–57
72	24	259.4	300.0	E–54

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† Representative cars; 22′-0″ c. to c. of trucks, 12′-0″ c. to c. of end trucks of coupled cars, 5′-6″ wheelbase of trucks.

Class GT gondolas; 36′-10.75″ c. to c. of trucks, 16′-0″ c. to c. of end trucks of coupled cars, 6-wheel trucks with 4′-4″ c. to c. of truck axles.

* These loads exceed the nominal capacities permitted by Section 105.

2. PLANS

201) Assembly plans shall be furnished showing the location of field connections and all information necessary for the purchaser to design and construct the pit and parts not furnished by the manufacturer. On request, the manufacturer shall furnish to the purchaser plans showing materials, stresses, and detailed dimensions for all scale parts.

3. WORKING STRESSES AND FORMULAS

301) General Working Stresses.—The maximal permissible unit stresses referred to in Section 1 are given below. In the stresses given, provision is made for the effect of impact caused by moving loads. For scales of 100 tons sectional capacity or less, if the dead load does not exceed 550 lb. per foot of track it may be neglected. For scales of greater than 100 tons sectional capacity, allowance must be made for a minimum dead load of 1000 lb. per foot of track. For scales of the respective types where the dead load exceeds the limits given, provision shall be made for the dead load according to the circumstances.

TABLE 2

ALLOWABLE UNIT STRESSES IN POUNDS PER SQUARE INCH FOR IRON AND STEEL

	Transverse Bending		*Direct Stress*		*Shear and Torsion*
Material	*Tension*	*Compression*	*Tension*	*Compression*	
Cast Iron (gray)					
Thickness of section					
0.25 in.	5000	8500	3500	10000	5000
0.3	4780	8130	3350	9560	4780
0.35	4600	7820	3220	9200	4600
0.4	4450	7560	3110	8900	4450
0.45	4320	7340	3020	8640	4320
0.5	4200	7140	2940	8400	4200
0.6	4020	6830	2810	8040	4020
0.7	3870	6580	2710	7740	3870
0.8	3740	6360	2620	7480	3740
0.9	3630	6170	2540	7260	3630
1.0	3540	6020	2480	7080	3540
1.1	3450	5860	2410	6900	3450
1.2	3380	5750	2370	6760	3380
1.3	3310	5620	2320	6620	3310
1.4	3250	5520	2270	6500	3250
1.5	3190	5420	2230	6380	3190
1.6	3140	5340	2200	6280	3140
1.8	3050	5180	2130	6100	3050
2.0	2970	5050	2080	5940	2970
2.5	2810	4780	1970	5620	2810
3.0	2690	4570	1880	5380	2690
3.5	2580	4390	1810	5160	2580
4.0	2500	4250	1750	5000	2500
Steel,					
Castings	10000	12000	10000	12000	8000
S.A.E. 1010 to 1020	10000	10000	10000	10000	7000
Pivots and Bearings					
S.A.E. 1095, hardened	24000	24000	24000	24000	
S.A.E. 6195 or 52100, hardened	30000	30000	30000	30000	

In designing cast iron members to sustain stress of any character, the maximum allowable unit stress shall be determined by the greatest thickness, exclusive of fillets, of the portion of the section carrying the stress being considered. In the main portion of a beam the thickness of the web or flange shall be used, whichever is the greater. The thickness of the flange shall be considered either as the average depth of the outstanding portion, or the breadth of flange outside to outside, whichever is less.

The bearing stress on steel pins shall not exceed 15,000 lb. per sq. in. on any diametral cross-section.

In proportioning rivets, nominal diameters shall be used.

The effective bearing area of a pin, bolt or rivet is the diameter of the member multiplied by the thickness of the metal upon which the member bears. In metal ⅜ in. thick and over, half the depth of countersink shall be omitted in calculating bearing area. In metal less than ⅜ in. thick, countersunk rivets shall not be assumed to carry bearing stress.

302) **High Strength Alloys.**—For materials intended or represented to be "high strength" alloys, unit working stresses other than those given in Table 2 may be used, provided these do not exceed 1/3 the unit stresses at the yield point established according to the test routine followed or prescribed by the American Society for Testing Materials for parts of the same analysis, heat treatment, and size, and provided further that the unit working stresses for any combination of gray iron and carbon steel exclusively shall not exceed those given in Table 2 for steel castings. The purchaser, if he requests, shall be furnished with sufficient data or test specimens to enable him to determine the physical properties of the particular "high strength" material proposed to be used.

303) Knife-Edge Bearing Stresses

a) For scales of 60 tons sectional capacity or less, the load per inch of knife-edge shall not exceed 6000 lb. for high carbon steel (S.A.E. 1095), or 7000 lb. for special alloy pivot steels (S.A.E. 6195 or 52100).

b) For scales of greater than 60 tons sectoinal capacity, the load per inch of knife-edge shall not exceed 5000 lb. for high carbon steel (S.A.E. 1095), or 6000 lb. for special alloy pivot steels (S.A.E. 6195 or 52100).

304) **Concrete Bearing Stresses.**—Bearing stresses on concrete shall not exceed 300 lb. per sq in. under scale lever stands, and 400 lb. per sq. in. at all other points.

305) **Projecting Pivots, Formula for Stresses.**—Where practicable pivots shall be supported their full length by integral parts of the containing lever. When impracticable so to support the pivots, external bending moments shall be determined as follows:

Let M be the required bending moment in inch-pounds
L, the length in inches of the moment arm
T, the distance in inches between the friction faces of the loop
W, the total load in pounds on both ends of the pivot
D, the length in inches of bearing in the loop
B, the width in inches of the boss, or sustaining member enveloping the pivot.

Then,

$$L = \frac{D}{2} + (T - B) + \frac{1}{4} \text{ in.}$$

$$M = \frac{WL}{2}$$

306) **Levers, Formulas for Loading.**—The main levers in a section shall be assumed to carry the sectional capacity equally divided between them. Each end extension lever shall be assumed to carry a load corresponding to 100 per cent of the sectional capacity. The portion of each middle extension lever carrying only the load from the end extension lever shall be assumed to carry a load corresponding to 100 per cent of the sectional capacity; the portion which carries the combined load from the end and inner section, 160 per cent of the sectional capacity. The transverse extension lever, the shelf lever, and beam shall be assumed to carry a load corresponding to 300 per cent of the sectional capacity.

307) **Bearing Pressures Under Foundations.**—The bearing areas of the foundation footings shall be such that the pressure under the footings will not exceed,

For fine sand and clay	4,000 lb. per sq. ft.
For coarse sand and gravel or hard clay	6,000 lb. per sq. ft.
For boulders or solid rock	20,000 lb. per sq. ft.

If the soil has not a safe bearing capacity equal to that of fine sand or clay, its bearing capacity shall be increased by drainage, by adding a layer of gravel or broken stone, or by driving piles.

4. LENGTH OF SCALE

401) Scale Length Defined.—The length of a scale is the length of its weigh-rails.

402) Scale Length—Limits.—The weigh-rails shall not extend beyond the center line of end sections. For general railway service the minimum scale length shall be 50 ft. For scales of 50 tons sectional capacity, the length shall not exceed 50 ft.

5. SCALE LEVERS

501) Qualities of Castings. Castings used for levers shall not be warped. They shall be clean, smooth, uniform, and free from blisters, blowholes, and shrinkage holes and cracks.

502) Machined Ways for Nose Irons.—Levers that are to be equipped with nose irons shall have those portions of the lever ends receiving them machined for the full distance over which the nose irons are to move.

503) Leveling Lugs.—In scales of the straight lever type, each lever shall be provided with leveling lugs for longitudinal alinement. In scales of the torsion lever type, leveling lugs shall be provided on the pipe or torsion member for transverse alinement and on the extension arm for longitudinal alinement. Each pair of lugs shall be spaced 11 in. apart. The leveling surfaces of each pair of lugs shall be finished to a common plane, which shall be parallel to the plane through the knife-edges of the end pivots.

504) Marking of Levers.—Figures denoting the ratio of each lever shall be cast or otherwise permanently marked on the lever.

505) Permanency of Adjustment.—The design, workmanship, and factory adjustment of all levers shall be such that the proper ratio of the lever arms will be maintained.

6. PIVOTS AND BEARINGS

601) Material.—The material used for pivots and bearings shall be either:

a) Special alloy pivot steel (S.A.E. 6195 or 52100), hardened to Rockwell C scale not less than 58, or

b) High carbon steel (S.A.E. 1095), hardened to Rockwell C scale not less than 60.

602) Design.—Pivots shall be so formed that the included angle of the sides forming the knife-edge will not exceed 90°, and the offset of the knife-edge from the center line of the pivot will not exceed 10 per cent of the width of the pivot for "machined in" pivots, or 15 per cent of the width of the pivot for "cast in" pivots.

603) Mounting

a) *Fastening.*—Pivots shall be firmly fastened in position without swaging or calking.

b) *Machined in Pivots, When Required.*—For scales of greater sectional capacity than 50 tons, main lever pivots shall be machine finished and fitted into machined ways.

c) *Continuous Contact Required.*—Pivots shall be so mounted that continuous contact of the knife-edges with their respective bearings for the full length of the parts designed to be in contact will be secured. In loop bearings the knife-edges shall project slightly beyond the bearings in the loops.

604) Position.—In any lever the pivots shall be so mounted that:

a) Each knife-edge will be maintained in a horizontal plane under any load within the capacity of the scale.

b) A plane bisecting the angle of a knife-edge will be perpendicular to the plane through the knife-edges of the end pivots.

c) The actual distance between the end knife-edges of any lever will not differ from the nominal distance by more than 1/64 in. per ft.

d) The knife-edges in any lever will be parallel.

605) Support for Projecting Pivots.—The reinforcing on the levers to support projecting pivots shall be tapered off to prevent accumulation of dirt next to the pivots and to provide proper clearances.

606) Fulcrum Distances.—The minimal distance between the fulcrum pivot knife-edge and the load pivot knife-edge in main levers of scales of 75 tons sectional capacity or less shall be 6.5 in. In scales of greater than 75 tons sectional capacity, the minimal distance shall be 8 in.

607) Location of Main Lever Load Knife-Edges.—The load knife-edges of main levers shall be so located that the center line of the live rails can be placed in the plane established by vertical lines through the centers of the knife-edges.

608) Design of Bearings.—Bearings and the parts supporting or containing them shall be so applied to the mechanism that permissible movement of the platform will not displace the line of contact between any bearing and the opposing pivot.

609) Mounting of Bearing Steels.—All bearing steels of the same nominal dimensions, or parts identification, shall be interchangeable or mounted in interchangeable bearing blocks. The interchangeable part shall be securely mounted in the part containing it.

610) Finish of Bearing Steels.—The bearing surfaces shall be brought to a smooth, true, and accurate finish to insure continuity of contact with opposing pivots.

7. NOSE IRONS

701) Design.—Nose irons shall be so constructed that:

a) They will be positioned by means of adjusting screws of standard size and thread.

b) They will be retained in position by means of screws or bolts of standard size and thread.

c) The surfaces of nose irons intended to be in slidable contact with the levers will be machined true, so as to secure an accurate fit in or on the levers.

d) When adjustments are made, the knife-edge will be held parallel to its normal position.

702) Screws and Bolts.—Adjusting and retaining screws and bolts shall be made of a corrosion-resistant material.

703) Retaining Device.—A device for retaining each nose iron in position shall be provided, and shall be so designed and constructed that:

a) It will be independent of the means provided for adjustment.

b) It will not cause indentations in the lever.

c) Loads applied to the scale will not cause tension in the retaining bolts.

d) The nose iron will remain in position when the retaining device is released.

704) Marking of Position.—The position of each nose iron as determined by factory adjustment shall be accurately, clearly, and permanently indicated by well defined marks on the lever and nose iron which meet on a common line.

8. LEVER FULCRUM STANDS

801) Qualities of Castings.—Castings for lever stands shall be clean, smooth, uniform, and free from blisters, blowholes, and shrinkage holes and cracks.

802) Proportions.—Lever stands shall be so designed, constructed and installed that, under any practical condition of loading, the resultant force through the bearing will fall within the middle third of the length and width of the base.

803) Bases for Lever Stands.—The base of any lever stand shall be smooth, or shall be finished in any suitable manner true within a tolerance of 1/32 in. to a plane perpendicular to a vertical line through the center of the knife-edge bearing carried by the upright portion of the stand.

804) Finish of Tops of Stands.—The top of any lever stand for receiving a bearing steel, cap, or block shall be finished to a tolerance of 1/32 in. of a plane parallel to the base.

805) Anchor Bolt Holes.—Two or more anchor bolt holes, not less than two inches in diameter, shall be provided in proper places in the base of every fulcrum stand, unless other equally effective means for anchorage are provided.

806) Tie Bars.—When tie bars for lever stands are used, contacting surfaces shall be machined.

9. LOOPS AND CONNECTIONS

901) Material.—The requirements for material and hardness of bearing surfaces in loop connections shall be the same as those herein prescribed for pivots and bearings.

902) Design.—In loops which form bearings for projecting pivots, the radius of the portion of the bearing making immediate contact with the knife-edge and the radius of the eye of the loop shall be not less than the longest side of the cross-section of the square pivot to be used in the loop, and like clearance shall be provided if pivots of other than square cross-section be used.

903) **Length.**—Loops in like connections, except when adjustable, shall be of the same length.

904) **Steelyard Rod.**—The steelyard rod shall be equipped with a turnbuckle.

904) **Locknuts.**—Bolts or turnbuckles used as parts of the connections shall be provided with locknuts.

10. CHECKS

1001) **Number, Type, and Kind.**—Weigh bridge checks shall be provided equivalent in functioning to not less than two longitudinal checks on each end and four transverse checks on each side, of the rod type. Checks of the rod and bumper types shall be adjustable.

1002) **Position.**—Checks shall be set in the same horizontal plane and as high as possible. Longitudinal and transverse checks designed to take tension shall be respectively parallel and perpendicular to a vertical plane through the center line of track.

1003) **Strength.**—When steel check rods are used on scales equipped with dead rails, the combined cross-sectional area in square inches of check rods at either end or side shall be not less than the sectional capacity in pounds divided by 60,000. On scales not equipped with dead rails, the combined check rods at either end or side shall be designed to resist a force of 66,000 lb. Plate checks or other types designed to take tension shall be calculated for equivalent strength.

11. WEIGH-BEAMS AND ACCESSORIES

1101) Design

a) *Limits for Beam Capacity.*—See Section 105.

b) *Full Capacity Beam.*—Except for special cases a weigh-beam of the full capacity type shall be provided.

c) *Shoulder Stop.*—On each weigh-beam a shoulder stop shall be provided to prevent the travel of the main poise back of the zero notch.

d) *Notches.*—On main bars the notches shall not be spaced closer than six to the inch. Each notch shall be so made that when the pawl rests in it a line projected from the center of the side of the notch nearer the zero graduation to the axis about which the pawl stem rotates will be perpendicular to that side of the notch.

e) *Pawl, or Latch.*—The tip of the point of the pawl or latch shall be of the same width as the notches of the beam, and shall be rounded off so that a small amount of dust or dirt in the bottom of the notch will not prevent the poise from assuming the correct position.

f) *Projections, or Recesses.*—Poises shall be designed with the object of reducing to a minimum the number of recesses that will retain foreign material.

g) *Poise Bearings.*—Each poise shall be constructed to move along its bar without side play. In full capacity beams, the main poises shall be equipped with roller or other form of frictionless bearing.

1102) Marking

a) *Intervals.*—For scales of less than 400,000 lb. nominal capacity, the notches and graduations on the main bar shall be made at 1000-lb. intervals.

b) *Length of Graduation Marks.*—For the main bar, the length of graduations other than those representing 0, 5, 10, 15, etc., thousand pounds shall be preferably 1.5 times the distance between their centers, but in no case greater than twice the distance between their centers. The length of graduations representing 5, 15, 25, etc., thousand pounds shall be not less than 1.5 times that of the intermediate graduations. The length of graduations representing 0, 10, 20, etc., thousand pounds shall be 0.75-in.

c) *Size of Figures.*—For the main bar, the zero graduation and every tenth graduation shall have its value in thousands of pounds (i.e., 0, 10, 20, etc.) marked by figures 3/8 in. in height, except the last graduation on the bar, which shall be marked in full (for example, 200,000 lb.). The 5s, 15s, etc., may or may not have the value in thousands of pounds marked, or may have a star or other device placed opposite the graduation. All numbers shall be placed directly above or below their respective graduations, and shall be within 1/16 in. to 1/8 in. of the graduation.

1103) Registering Beams

a) *Where Required.*—Every scale subject to the requirements for weighing grain (Docket 9009) shall be equipped with a full-capacity, type-registering weigh-beam.

b) *Fractional Bar Stops.*—On registering weigh-beams, the fractional poise shall be equipped with means to insure a positive stop at any 20-lb. interval, and a stop shall be provided to prevent the movement of the fractional poise beyond its proper travel in either direction.

c) *Operating Lever.*—On registering weigh-beams, a substantial type of hand grip shall be provided to facilitate the registration of the weight. The natural operation of the registering mechanism shall not cause lateral displacement of the beam.

d) *Receptacle for Weight Ticket.*—On registering beams, means shall be provided to prevent the placing of the weight ticket in its receptacle in any position in which an incorrect weight can be registered.

e) *Type Figures.*—On registering beams, type figures shall be made of material sufficiently hard that under the designed conditions of use the figures will not become battered or defaced. The figures shall be plain and raised sufficiently to insure a clear impression upon the weight ticket. They shall be so attached that they cannot become loosened or detached without a positive indication that the beam is out of order.

1104) Fractional Bars.—For registering beams the graduations for the fractional bar shall be placed at 20-lb. intervals up to and including 980 lb., or if the fractional bar corresponds to a full 1,000 lb., the last figure shall be marked to read 999 lb. Non-registering beams shall be graduated in 50-lb. intervals except for special cases.

1105) Balance Ball.—The position of the balance ball shall be vertically adjustable. Unless otherwise required by law or regulation, longitudinal movement shall be controlled by means of a self-contained, hand-operated screw or other device which will not require the ball to be rotated.

1106) Counterbalance Weights.—If counterbalance weights are to be used, the lower end of the hanger stem shall be threaded, a cup for the loose balancing material shall be screwed to the lower end of the stem and each additional weight shall be provided with an elongated hole in the center through which the hanger stem may pass. When no counterbalance weights are necessary on top of the counterbalance cup, the cavity shall be closed by a cover, secured in a positive manner. No counterbalance weights shall be used in any place in the scale, except at the beam. No slotted counterbalance weights shall be used.

1107) Ratio.—A pivot with a loop shall be provided at the beam tip. The ratio to this pivot shall be 7,000, or 10,000. The ratio shall be plainly and permanently stamped on the beam.

1108) Identification of Parts.—Each beam shall be given a serial number which shall be stamped on the beam. The pivots, poises, and fractional bar shall have stamped upon them identification marks to show to which beam each belongs, and the pivots shall be so marked as to indicate their proper positions in the beam.

1109) Factory Adjustment of Notches.—Each beam notch shall be adjusted to within 0.002 in. of the nominal distance from the zero notch.

1110) Beam Fulcrum Stand

a) The weigh-beam shall be supported on a stand fitted with compensating bearings. Beam fulcrum stands shall be so designed, constructed and installed that the resultant line of forces applied through the bearing carried by the stand will fall within the middle third of the length and width of the base.

b) *Height.*—The height of the stand measured from the bottom surface of the base to the pivot bearing surface shall not exceed 13 in.

c) *Finish.*—The bearing surface of the base of the stand shall be finished to a plane perpendicular to the axis of the upright portion of the stand, and the knife-edge line of the bearing shall be parallel to the base.

1111) Trig Loop

a) *Play of the Beam.*—The play of the beam in the trig loop shall be not more than 2 per cent of the distance from the trig to the fulcrum pivot, nor less than 0.9 in.

b) *Pointer.*—The beam shall be fitted with an indicator to be used in conjunction with a graduated target or other device on the trig loop to indicate a central position in the trig loop when the beam is horizontal.

c) *Material.*—The contact parts of the trig loop shall be made of a non-magnetic material.

1112) Beam Support.—The beam fulcrum stand and trig loop stand shall be supported on a metal shelf mounted on metal pillars, or equivalent in strength and durability. The shelf shall be sufficiently rigid that, within the capacity of the scale, deflection cannot occur to such an extent as will affect the weighing performance.

12. ANTI-FRICTION POINTS AND PLATES

1201) Material and Design.—Hardened steel anti-friction contacts shall be used to limit longitudinal displacement between knife-edges and bearings. They shall be smooth and so designed and applied as to provide contact at points on the knife-edge line.

1202) Clearances.—The total clearance between anti-friction plates and points shall not exceed 1/16 in. on the beam, ⅛ in. on the shelf lever, and ¼ in. on all other levers. The minimal clearance shall be not less than one-half these respective amounts.

13. CLEARANCES

1301) Minimum Clearance.—The clearance around and between the fixed and live parts of the lever system shall be at least ¾ in. except at points where other clearances are specified.

14. INTERCHANGEABILITY

1401) Units or parts of units intended to be interchangeable with like units or parts in scales of the same design and manufacture, shall be identified on the scale drawings or in the subject matter of the proposal in such manner as will clearly indicate the interchangeable parts, the manner of replacement, and the adjustments required, if any, after replacement.

15. SCALE WEIGH-BRIDGES

1501) Type of Girders.—Weigh-bridge girders shall be so designed that the joints over the centers of bearings will admit vertical flexure without deranging the sections.

1502) Weigh-Bridge Bearings.—The surfaces of weigh-bridge bearings intended to make contact with the bridge girders shall be finished so that, when in position, all the bearing surfaces will be within 1/32 in. of the same horizontal plane and parallel to it. To secure proper alinement of parts, the diameter of the bolt holes in the weigh-bridge bearings and in the girders shall exceed the diameter of the bolts fastening the bearings to the girders by ½ in.

1503) Steel Specifications.—Structural steel work shall conform to the Specifications for Steel Railway Bridges published by the American Railway Engineering Association.

1504) Girders—Size and Strength.—Table 3 gives the required section moduli for weigh-bridge girders for scales of different standard lengths and sectional capacities.

TABLE 3

WEIGH-BRIDGES FOR RAILWAY TRACK SCALES

Length of Scale (ft.)	*Length of Span (ft.)*	*Section Modulus of one girder for scales of sectional capacity in tons as shown*					
		50	*60*	*75*	*100*	*greater than 100 Cooper's*	
						E–60	*E*–70
42	14	127.0	152.4	190.5	254.1	212.7	245.7
46	15.33	135.7	162.8	203.5	271.3	251.6	290.6
50	16.67	152.3	183.0	228.5	304.7	290.8	335.8
56	18.67	176.9	212.3	265.4	353.8	350.1	404.1
60	20	192.9	231.4	289.2	385.7	401.3	463.2
66	22	219.1	262.9	328.6	438.2	478.5	552.2
72	24	244.9	293.9	367.3	489.7	566.6	642.1

Dead load neglected for scales of 100 tons sectional capacity or less; 500 lb. per foot of track per girder for scales of greater than 100 tons sectional capacity (see Section 301).

1505) Bracing.—Each weigh-bridge span shall be designed for a lateral force of 200 lb. per lin. ft., plus four per cent of the sectional capacity of the scale, uniformly distributed along the top of the live rail.

1506) Diagonal Bracing.—Diagonal bracing shall consist of not less than $3 \times 3 \times \frac{3}{8}$-in. angles, or equivalent. Not less than three diagonals per span shall be used.

1507) Transverse Bracing.—To carry the lateral load to the knife-edges of the main levers, each span shall be provided at its ends with transverse bracing, for which the section modulus shall be not less than that determined by the formula,

$$S = \frac{1}{4} \frac{(0.04C + 200L)\,d}{10{,}000}, \text{ wherein}$$

S, is the section modulus
C, is the sectional capacity in pounds
L, is the length of span in feet
d, is the distance in inches from the knife-edge of main lever to top of live rail, or to top flange of girder if ties are used, or when pedestals are braced to resist tipping transversely to the girder.

Intermediate transverse bracing shall also be used at intervals not exceeding six feet, having a section modulus not less than that used at the ends of the span.

1508) Stiffeners.—Not less than one pair of stiffener angles, other than splicing angles, shall be provided over each bearing of the girders in each span of the weigh-bridge. The ends of these stiffeners shall be milled to fit the fillets of the girder flanges.

1509) Weigh-Rail Pedestals.—The weigh-rails shall be carried on metal pedestals spaced not over 30 in. center to center mounted on metal ties or directly on the weigh-bridge. The tops of pedestals shall be machined. The bottoms of the pedestals shall be machined unless type metal or equivalent is to be poured between the bottoms and the surfaces supporting them. Pedestals shall be so designed that they will transfer the lateral load specified in Section 1505 to the weigh-bridge. Tie rods shall be provided to prevent spreading of the rails due to the wedging action of wheel flanges.

1510) Fabrication and Assembly.—In order to avoid distortion each pair of weigh-bridge girders shall be fabricated complete with diagonal and transverse bracing in the shop under proper inspection where practicable. Where this method is impracticable, and where field assembly is necessary, each pair of girders shall be placed in proper alinement and the bracing then introduced and secured by bolts or rivets.

1511) Weigh-Rails—Length and Weight.—The weight and section of the weigh-rails shall be the same as those of the dead rails (see Section 1803). Full-length rails shall be used.

1512) Clearance along Weigh-Rails.—The clearance between weigh-rails or their pedestals and the rigid deck shall be not less than 1.5 in., and the openings shall be protected from weather and dirt.

16. PROTECTION FROM CORROSION

1601) The finish and treatment of all surfaces shall be such as to insure good appearance and satisfactory resistance to corrosion. The surface treatment shall be durable and appropriate for the intended uses.

17. APPROACH RAILS

1701) Anti-Creep Provisions.—Positive means shall be provided to prevent creeping of approach rails, and to maintain a clearance which shall be not less than ¼ in. nor more than ¾ in. between the approach rails and the weigh-rails unless some special means is used to reduce impact when wheel loads pass from approach rails to weigh-rails.

1702) Easer Joints.—Easer joints, or load transfer devices, if used, shall be so constructed as to leave no lateral or vertical restraint upon the weigh rails when the device is unloaded.

18. DEAD RAILS, AND DEAD RAIL BEAMS

1801) Dead Rails: When Required.—All scales except those so located where they cannot be subjected to locomotive or other loads in excess of the sectional capacity, and excepting also scales of greater than 100 tons sectional capacity, shall be equipped with dead rails.

1802) Elevation.—Dead rails shall be constructed to the same elevation as the weigh rails.

1803) Weight of Rails.—Rails shall be as specified by the purchaser, except that the following minimum requirements shall govern. When supported on floor beams 30 in. center to center the weight of rails for corresponding axle loads shall be not less than shown in the table below. For greater spacing of the floor beams the weight of rails shall be correspondingly increased.

Class of Locomotive Load	*Weight of Rail per Yard*
E–50	85 lb.
E–55	85
E–60	90
E–65	100
E–70	112

1804) Transverse Beams Supporting Dead Rails

a) *Structural Steel Work.*—Structural steel work shall conform to the American Railway Engineering Association Specifications for Steel Railway Bridges.

b) *Strength.*—The following table gives the section moduli for floorbeams corresponding to the loads and other conditions stated.

Assumptions Dead rail offset 16 inches
Floor beams 30 inches center to center
75 per cent of axle load carried by one beam
Dead rails 59 inches center to center
Fiber stress, 10,000 pounds per square inch.

Class of Locomotive Loading	*Required Section Moduli* *Floor Beam Supports 11 ft. 0 in. c. to c.*	*Floor Beam Supports 11 ft. 6 in. c. to c.*
E–50	74.6	79.9
E–55	82.0	87.9
E–60	89.5	95.9
E–65	96.9	103.9
E–70	104.4	111.9

19. DECK

1901) Type.—Unless a scale is used to weigh other loads than freight cars of standard gage, the deck shall be of the fixed type.

1902) Construction.—The material for the deck shall be surfaced to conform to safety requirements, shall be sufficiently strong to support the incidental traffic, and shall be waterproof.

1903) Clearance.—The clearance between the bottom of the fixed deck beams, or deck supports, and the girders forming the weigh-bridge shall be not less than two inches.

20. EXCLUSION OF DIRT AND PRECIPITATION

2001) Means shall be provided to prevent accumulation of dirt and other foreign material in or about the pivots, bearings, or other parts, whereby interference with the action of the scale or undue deterioration of any part of the scale structure might result.

21. LIGHTING

2101) Weigh-beam, Scale House and Deck.—Lighting of the weigh-beam, scale house and deck shall be provided adequate for the needs of safe operation and to enable the weigher to read the weigh-beam and observe car numbers and position of car wheels with certainty.

2102) Pit.—The pit shall be provided with sufficient illumination to permit the ready and complete inspection of the scale parts.

22. LOCATION AND ELEVATION

2201) **Foundation.**—Scales shall be so located that an adequate foundation and at least 50 ft. of tangent track at each approach to the weigh-rails can be provided.

2202) **Elevation.**—The scale shall be raised with respect to the other tracks of the yard to such an elevation that drainage of the surface water will be away from it. Means shall be provided to prevent surface water between the rails of the scale track from running into the pit.

2203) **Right-Handed Beam.**—Scales shall be so located that a right-handed beam can be used without levers exclusive of the shelf lever between the transverse extension lever and the beam.

23. FOUNDATION AND PIT

Note.—This section presumes that scale pits fully enclosing the scale mechanism are necessary. When conditions permit, however, consideration should be given to the possibility of installing scales on foundations without side walls since this conduces to better maintenance, especially in the lower latitudes.

2301) **Material.**—All scale foundations shall be constructed of concrete. The quality of materials and methods of mixing and placing the concrete shall conform to the specifications of the American Railway Engineering Association for Class A concrete.

2302) **Dimensions of Pit.**—The depth of the scale pit shall be not less than seven feet from the base of the rail to the finished floor. The width between faces of side walls shall be not less than ten feet, provided there shall be a horizontal clearance of not less than 16 in. between the faces of the side walls and the scale parts below the weigh-bridge girders and above the bases of the stands. The length inside the end walls shall be not less than two feet greater than the assembled length of the scale.

2303) **Walls of Pit.**—The side and end walls shall be not less than 15 in. (preferably 18 in.) thick at the top, provided, that for scales used exclusively for weighing grain and which are not equipped with dead rails the pit walls may be 12 in. thick at the top. The foundation walls of the scale house shall be not less than 12 in. thick at the top and shall be solidly formed to the side walls of the scale pit.

2304) **Waterproofing.**—Where necessary to prevent seepage of water through foundations, scale pits shall be membrane waterproofed, or waterproofed by methods equally effective.

2305) **Drainage.**—The pit floor shall be pitched to a common point for drainage, and shall be smooth and free from pockets in which water may stand. If the pit floor is below subsurface water level, the pit shall be drained from its lowest point into a sump adequately equipped with automatic means for removal of water as it collects.

2306) **Approach Walls.**—Approach walls, or piers of concrete shall be built to extend at least 15 ft. (preferably 25 ft.) from the pit face of the end wall at the approach and back under the track to preserve line and surface of approach tracks. They may be built in one solid mass of concrete or may consist of two parallel walls or piers; however, the latter construction shall have a single footing supporting both walls. Where necessary to secure safe bearing capacity the approach walls shall extend to the same depth as the pit walls.

2307) **Wall Batter.**—Wall surfaces next to earth subject to freezing shall be constructed with a batter of not less than one to twelve.

2308) **Footings or Piers for Lever Stands.**—Concrete footings or piers supporting the lever stands shall be not less than 18 in. thick. Their tops shall be above the floor a sufficient distance to prevent the accumulation of water under the bases of stands, and shall be finished to exact level and elevation to receive the lever stands directly without the use of shims or grouting. If the scale is of a type having main levers or parts of the bearing assemblies that hang below the bases of the main lever stands, the piers shall be provided with recesses of a size to give clearance of not less than 1.5 in., and so formed as to prevent accumulation of dirt. (See also Section 307.)

2309) **Pit Floor.**—The floor of the pit may be a mat of concrete approximately as thick as that required to support the main lever fulcrum stands, or if local conditions permit, the thickness may be reduced to not less than six inches. (See Section 2305 for drainage requirements.)

2310) **Anchor Bolts.**—Anchor bolts embedded in concrete a minimum of 15 in. shall be provided in foundations for lever stands to match the bolt holes provided for securing the stands.

2311) **Floating Levers.**—Floating levers shall be anchored to the foundation to resist not less than twice the up-pull produced by the capacity live load.

2312) **Deck Beam Supports.**—For deck beam supports, inverted T-rails, or old rails, or equally effective metal bearings shall be set in each side wall of the pit with the center of bearings not less than six inches from the inside of the pit wall. Such bearings shall not be fastened to transverse beams.

2313) **Beam Foundations.**—The pillars supporting the weigh-beam shelf shall rest upon a reinforced concrete floor, or steel beams, or reinforced concrete beams, but the pillars and supporting beams, if used, shall be independent of the scale house floor if it is of timber. When necessary to install the scale beam in a building other than a regular scale house, the pillar support shall rest on foundations independent of the building.

2314) **Ventilation.**—Scale pits shall be ventilated to meet the needs of each particular case, the object being to prevent condensation on the metal parts.

2315) **Entrance to Scale Pit.**—Entrance to the scale pit shall be either through the floor of the beam house or the foundation wall, preferably the latter. The opening shall be closed by a door suitably fastened to prevent the entry of unauthorized persons.

2316) **Grain-Weighing Scales — Cleaning.**—When available, compressed air shall be piped into the pit of each scale subject to the requirements for weighing grain (Docket 9009). Sufficient hose and a suitable nozzle to reach all parts of the scale under the deck for the purpose of blowing out dust shall be provided.

24. SETTING OF THE SCALE

2401) **Fastening of Stands.**—After alining the lever stands the anchor bolt holes in the castings shall be filled with cement, or other suitable material, washers applied to the anchor bolts, and the nuts run solidly home.

2402) **Alinement.**—All levers shall be level and connections plumb.

25. SCALE BEAM HOUSE

2501) **Design.**—Except where the beam is mounted in an adjacent building, a suitable and substantial scale beam house shall be provided to house a weigh-beam and provide a weighing office. The minimum inside width of the scale house shall be four feet, and the minimum length shall be sufficient to allow the installation of a shelf and weigh-beam of proper capacity together with accessories. It shall be provided with a bay window, or front and end windows, located with the sill about on a level with the top of the beam shelf, and of sufficient size to give the weigher a clear and unobstructed view of the scale deck and approaching cars. The windows shall be glazed with clear glass, or clear wire glass, free from imperfections.

2502) **Clearances**

a) *Beam Shelf.*—A clearance of not less than one inch shall be provided between the inside of the scale house and beam supports and shelf.

b) *Track.*—The lateral clearance between the scale house and the center of any track shall be not less than 7 ft. 6 in., if not otherwise required by law, or the purchaser.

2503) **Ventilation.**—A suitable roof ventilator shall be provided for the scale house.

26. SENSIBILITY RECIPROCAL

2601) **Definition.**—The sensibility reciprocal is the change in load required to turn the weigh-beam from a position of equilibrium in the center of the trig loop to a position of equilibrium at either limit of its travel.

2602) **Limit.**—The sensibility reciprocal shall not exceed 50 lb.

27. TOLERANCE

2701) The tolerance in excess or deficiency on the first field test, after installation corrections, is 0.05 per cent of the applied load, or 50 lb. per 100,000 lb. of applied load, for any position of a test weight car on the weigh-rails. The procedure outlined in the "Definition of a Standard Test of a Railway Track Scale" shall be followed.

28. SCALE SHED

2801) Scales subject to the requirements for weighing grain (Docket 9009) shall be covered by a shed equipped with end doors.

29. CAR PULLERS

2901) Installation.—When a car puller is used the sheaves shall be located beyond each end of the scale so that the pull on the rope or cable will not produce an appreciable side pull on the scale. The angle of pull shall not exceed 6 degrees.

SPECIFICATIONS FOR MOTOR TRUCK, BUILT-IN, SELF-CONTAINED AND PORTABLE SCALES

Since the specifications for motor truck, built-in, self-contained and portable scales for railway service were adopted by the Association in March, 1935, some developments occurred which made review desirable in order better to accommodate them, not only to the use of the railways, but also to the broader purpose of commercial standardization.

With a view to meeting the current and anticipated needs of commerce, leaders in the art have considered that the schedule of sizes and capacities of motor truck scales, which at the inception of the work of generally revising these specifications four years ago seemed adequate, is no longer so. After conference with the manufacturing interests, and further study of facts, your Committee decided to recommend the inclusion in the schedule of certain sizes and capacities the trade now demands, and the deletion of others no longer of commercial consequence.

Although the basic requirements for design, workmanship and materials remain in substance the same, nevertheless the proposed changes involved the addition of detail and rearrangement of subject-matter. This, together with revision of subject-matter to give consistency of appearance with similar requirements in other codes (particularly the four-section railway track scale specifications and others currently undergoing revisions), left these specifications with so much new face that offering them as a completely revised version seemed advisable.

Accordingly, your Committee offers the following revision of "Specifications for the Manufacture and Installation of Motor Truck, Built-in, Self-contained and Portable Scales for Railway Service", and recommends its adoption as Manual material in place of existing Manual material under the same title.

SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF MOTOR TRUCK, BUILT-IN, SELF-CONTAINED AND PORTABLE SCALES FOR RAILWAY SERVICE—1936

Introduction

Motor truck, built-in, self-contained and portable scales for railway service of the kind known to the trade as knife-edge scales are covered by these specifications. The application is basically to scales equipped with weigh-beams. For scales of the automatic indicating and/or recording type, and with automatic indicating and/or recording attachments, the specifications apply to all parts except the mechanism essential to the automatic feature.

1. Information to be Supplied by Purchaser

To assure definiteness in handling proposals and acceptance of material when manufacturers or contractors are required to furnish scales, or are invited to offer bids to furnish scales conforming to the specifications herein, the information indicated in the schedule below must be supplied by the purchaser.

101. State the nominal capacity of the scale and the size of platform.

102. If a motor truck scale, is a plain or registering weigh-beam required?

103. If a built-in scale, is a full-capacity weigh-beam required?

104. If a built-in or self-contained scale and a definite ratio is required at the beam tip, state what it is. (See Section 1304.)

105. State the material of which the counterpoise weights are to be made. (See Section 1314.)

106. For motor truck and built-in scales, state what material is required for the platform.

107. If a motor truck scale, is the weigh-bridge to be furnished completely fabricated?

108. If a built-in scale, is the weigh-bridge, platform and coping material to be furnished with the scale?

109. For motor truck and built-in scales, state special requirements, if any, for clearance between the platform and weigh-beam.

110. What installation service, if any, is to be furnished by the firm supplying the scale?

2. Classes of Scales

201. The classes of scales covered by these specifications are the following:

(a) **Motor Truck Scales:** A motor truck scale is one designed for the purpose of weighing power-driven highway vehicles and trailers.

(b) **Built-in Scales:** A built-in scale is one, other than of the motor truck class, marketed without the frame supporting and containing the main lever system, and designed to require preparation of a foundation on the premises where used.

(c) **Self-contained Scales:** A self-contained scale is one enclosed and supported by its own frame, marketed as a complete weighing unit and designed for use in a permanent location.

(d) **Portable Scales:** A portable scale is one mounted on wheels or otherwise designed for easy movement from place to place.

3. Capacities and Sizes

301. Definitions

(a) **Capacity:** The capacity of a scale is the heaviest load that can be applied to the platform without inducing stresses in any member in excess of those specified in Section 5, the conditions of concentration of loading being those required in Section 6.

(b) **Nominal Capacity:** The nominal capacity of a scale is the largest weight indication obtainable by use of all the reading elements in combination, fractional elements totaling 2.5 per cent or less of the remaining reading elements being neglected.

(c) **Size:** The size of a scale is expressed by the dimensions of the platform surface. In rectangular platforms, the first dimension given is that of the platform edge nearest the beam.

302. **Nominal Capacities and Sizes:** The nominal capacities and sizes of scales in the different classes covered by these specifications shall be as given in Tables **1-(a) and 1-(b).**

TABLE 1–(a)

MOTOR TRUCK SCALES—NOMINAL CAPACITIES AND SIZES

Maximal Nominal Capacity (pounds)	*Platform Size (feet)*
36,000	18 by 9
60,000	20 by 9, 20 by 10, 24 by 9, 24 by 10, 28 by 10, 34 by 10
70,000	28 by 10, 34 by 10, 40 by 10

As regards design, construction, workmanship and materials, these specifications apply only to scales having capacities within the limits given in the above table. The design data (Sections 5 and 6, below) do not hold for greater capacities, or for scales with greater platform lengths than 40 ft.

TABLE 1–(b)

BUILT-IN, SELF-CONTAINED AND PORTABLE SCALES—NOMINAL CAPACITIES AND SIZES

Class of Scale	*Nominal Capacity (pounds)*	*Size (feet)*
Built-in	10,000	6 by 5, 8 by 6, 9 by 7
	20,000	8 by 6, 9 by 7
		(inches)
Self-contained	2,500	46 by 38
	4,000	48 by 48
	10,000	72 by 54
Portable	1,000	18 by 27
	2,000	25 by 32

(In Tables 1-(a) and 1-(b), the intent of the specifications is that minor variations from the nominal capacities and dimensions given for platform sizes are immaterial, and being otherwise in conformance with these specifications, the usually manufactured stock sizes are satisfactory.)

4. Plans

401. The purchaser shall, upon his request, be furnished written information showing the material of which scales proposed to be furnished are made, and if any material be not among those to which the safe stresses listed in Section 5 apply, the chemical and physical properties must be given in sufficient detail to permit confident judgment of the safe stresses or factors of safety used in design.

402. For motor truck and built-in scales, the purchaser shall be furnished assembly plans showing the location and size of open holes for field connections and all information necessary for the design and construction of the pit or all parts required and not furnished with the scale. (See also Section 1701.) Upon request in the invitation for bids, the purchaser shall be furnished drawings or descriptions in sufficient dimensional detail to permit the customary design calculations for stresses and to allow adequate checking of the design requirements for construction, finish and workmanship.

5. Working Stresses, and Formulas

501. In any scale loaded as required in Section 6, the following unit stresses shall not be exceeded. The stresses given include a sufficient allowance for impact.

TABLE 2

WORKING STRESSES IN POUNDS PER SQUARE INCH

	Transverse Bending		*Direct Stress*		*Shear and Torsion*
Material	*Tension*	*Compression*	*Tension*	*Compression*	
Cast Iron (gray), Thickness of section.					
0.25″	5000	8500	3500	10000	5000
0.3	4780	8130	3350	9560	4780
0.35	4600	7820	3220	9200	4600
0.4	4450	7560	3110	8900	4450
0.45	4320	7340	3020	8640	4320
0.5	4200	7140	2940	8400	4200
0.6	4020	6830	2810	8040	4020
0.7	3870	6580	2710	7740	3870
0.8	3740	6360	2620	7480	3740
0.9	3630	6170	2540	7260	3630
1.0	3540	6020	2480	7080	3540
1.1	3450	5860	2410	6900	3450
1.2	3380	5750	2370	6760	3380
1.3	3310	5620	2320	6620	3310
1.4	3250	5520	2270	6500	3250
1.5	3190	5420	2230	6380	3190
1.6	3140	5340	2200	6280	3140
1.8	3050	5180	2130	6100	3050
2.0	2970	5050	2080	5940	2970
2.5	2810	4780	1970	5620	2810
3.0	2690	4570	1880	5380	2690
3.5	2580	4390	1810	5160	2580
4.0	2500	4250	1750	5000	2500
Steel					
Castings	10000	12000	10000	12000	8000
Pivots and Bearings					
S.A.E. 1095, hardened	24000	24000	24000	24000	
S.A.E. 6195 or 52100, hardened	30000	30000	30000	30000	

S.A.E. 1010 to 1020	*For Live Loads and Lateral Forces*	*For Dead Loads*
Tension, axial (net section), transverse bending, and diagonal in webs of girders and rolled beams where maximum shear and bending simultaneously occur	12,000	24,000
Bolts, area at root of threads	7,500	15,000
Compression, axial and transverse bending	12,000	24,000
Shear, girder webs, gross section	7,500	15,000
Pins and shop driven rivets	9,000	18,000
Turned bolts and power driven field rivets	7,500	15,000
Unfinished bolts and hand driven rivets	6,000	12,000
Bearing, pins, steel parts in contact, and shop driven rivets	18,000	36,000
Turned bolts and power driven field rivets	15,000	30,000
Unfinished bolts and hand driven rivets	12,000	24,000
Rollers (lb. per lin. in.), where *d* is the roller diameter in inches	450 *d*	900 *d*

Timber (used only for flooring and spiking strips), see Sections 514 and 24.

In designing cast iron members, the maximum allowable unit stress of any character shall be determined by the greatest thickness, exclusive of fillets, of the portion of the section carrying the stress being considered. In the main portion of a beam the thickness of the web or flange shall be used, whichever is the greater. The thickness of the flange shall be considered either as the average depth of the outstanding portion or the breadth of flange outside to outside, whichever is less.

In proportioning rivets, nominal diameters shall be used.

The effective bearing area of a pin, bolt or rivet is the diameter of the member multiplied by the thickness of the metal upon which the member bears.

In metal $3/8$ in. thick and over, half the depth of countersink shall be omitted in calculating bearing area. In metal less than $3/8$ in. thick, countersunk rivets shall not be assumed to carry stress.

502. **High Strength Alloys:** For materials intended or represented to be "high strength" alloys, unit working stresses other than those given in Table 2 may be used, provided these do not exceed one-third the unit stress at the yield point established according to the test routine followed or prescribed by the American Society for Testing Materials for parts of the same analysis, heat treatment and size, and provided further that the unit working stresses for any combination of gray iron and carbon steel exclusively shall not exceed those given in Table 2 for steel castings. The purchaser, if he requests, shall be furnished with sufficient data or test specimens to enable him to determine the physical properties of the particular "high strength" material proposed to be used.

503. **Knife-edge Bearing Stresses:** The load per inch of knife-edge shall not exceed 5000 pounds for high carbon steel (S.A.E. 1095) or 6000 pounds for special alloy pivot steel (S.A.E. 6195 or 52100).

504. **Concrete Bearing Stresses:** The stress to be allowed for bearing on concrete shall not exceed 300 pounds per square inch.

505. **Projecting Pivots—Formula for Stresses:** Where practicable, the pivots shall be supported their full length by integral parts of the lever. Where impracticable so to support the pivots, external bending moments shall be determined as follows:

Let M be the required bending moment in inch-pounds,
L, the length in inches of the moment arm,
W, the total load in pounds on both ends of a pivot,
D, the length in inches of bearing in the loop,
T, the distance in inches between friction faces of the loop,
B, the width in inches of the boss or sustaining member enveloping the pivot

Then

$$L = D/2 + (T - B) + 1/4''$$

And

$$M = WL/2$$

506. **Stringers, Floor Beams, and Floor Slabs:** When loads are or may be applied to the scale platform from any direction, the following principles of design applicable to stringers, floor beams, and floor slabs shall be used. If, for any reason of design or installation, traffic over the scale is constrained to follow within definite limits a given direction, the stringer and floor beam sections, and the flooring may be calculated to conform to the established traffic conditions.

507. **Shears and End Reactions in Stringers and Floor Beams:** In calculating end shears and end reactions in transverse floor beams and longitudinal beams and stringers, no lateral or longitudinal distribution of the vertical concentrated live loads shall be assumed.

508. **Bending Moment in Stringers:** In calculating bending moments in longitudinal beams or stringers, no longitudinal distribution of the loads shall be assumed. The lateral distribution shall be determined as follows:

(a) **Interior Stringers:** Interior stringers shall be proportioned for loads determined in accordance with the following table, except that when the limiting stringer spacings are exceeded, the stringer loads shall be determined by the reactions of live loads, assuming the flooring between stringers to act as a simple beam.

Kind of Floor	*Fraction of Wheel Load to Each Stringer*	*Limiting Stringer Spacing in Feet*
Plank	S/4.0	4.0
Strip 4 in. in thickness or wood block on 4-inch plank sub-floor	S/4.5	4.5
Strip 6 in. or more in thickness..........	S/5.0	5.0
Concrete	S/6.0	6.0

$S =$ spacing of stringers in feet.

(b) **Outside Stringers:** The live load supported by outside stringers shall be the reaction of truck wheels, assuming the flooring to act as a simple beam between stringers.

(c) **Total Capacity of Stringers:** The combined load capacity of the beams in a panel shall not be less than the total live and dead load on the panel.

509. **Bending Moment in Floor Beams:** In calculating bending moments, no transverse distribution of loads shall be applied.

If longitudinal stringers are omitted and the floor is supported directly on the floor beams, the latter shall be proportioned for a fraction of the concentrated live loads as indicated in Section 508-(a), substituting "floor beams" for "stringers", except that when the limiting floor beam spacing is exceeded the floor beam loads shall be determined by the reactions of the loads, assuming the flooring between floor beams to act as a simple beam.

510. **Distribution of Wheel Loads on Concrete Slabs: Bending Moment:** In calculating bending stresses due to wheel loads on concrete slabs, no distribution in the direction of the span of the slab shall be assumed. In the direction perpendicular to the span of the slab, the wheel load shall be considered as distributed uniformly over a width of slab which is termed the "effective width" and is obtained from the following formulas in which

S is the span of slab in feet
W is the width of tire in feet
D is the distance in feet from the center of the near support to the center of wheel, and
E is the "effective width" in feet for one wheel.

Case I—Main reinforcement parallel to direction of traffic:

$E = 0.7\,S + W$, in which E shall have a maximum value of 7.0 feet.

When two wheels are so located on a transverse element of the slab that their effective widths overlap, the "effective width" for each wheel shall be $\frac{1}{2}\ (E + C)$, in which E is the value determined by the formula above and C is the distance between centers of wheels.

Case II—Main reinforcement perpendicular to direction of traffic:

$E = 0.7\ (2D + W)$.

For this case, the bending moment on a strip of slab one foot in width shall be determined by placing the wheel loads in the position to produce the maximum bending, assuming no distribution; determining the effective width for each wheel; and assuming the load of each wheel on the one-foot strip to be the wheel load divided by its respective effective width.

The design assumption of Case II does not provide for the effect of loads near unsupported edges. Therefore, at locations where the continuity of the slab is broken, the edges of the slab shall be supported by diaphragms or other suitable means.

511. **Shear in Slabs:** Slabs designed for bending moment in accordance with the foregoing rules and for the wheel loads contemplated by these specifications may be considered adequate for shear without special reinforcement.

512. **Placing of Reinforcement:** The minimum clear distance between parallel bars shall be 1½ times the diameter of round bars, or 1½ times the diagonal of square bars. The maximum spacing shall be 2½ times the slab thickness. Bars parallel to the face of any member shall be imbedded a clear distance of not less than one inch from the face.

513. **Members Supporting Deck Overhang:** In calculating bending moments, and shears and reactions in members supporting the flooring outside the main girders, no lateral or longitudinal distribution of the vertical live loads shall be assumed.

514. **Floor Plank:** In motor truck and built-in scales, when plank is used for platform covering, the thickness shall be not less than one-eighth the distance between supports, provided that in no instance shall the actual thickness be less than three inches. In motor truck scales, the nominal width shall not be less than eight inches. Spiking timbers, if used, shall be fastened in such manner as to prevent slipping of the scale deck.

515. **Bearing Pressures Under Foundations:** The bearing areas of the foundation footings shall be such that the pressure under the footings will not exceed—

For fine sand or clay	4,000 lb. per sq. ft.
For coarse sand and gravel or hard clay	6,000 lb. per sq. ft.
For boulders or solid rock	20,000 lb. per sq. ft.

If the soil has not a safe bearing capacity equal to that of fine sand or clay, its bearing capacity shall be increased by drainage, by adding a layer of gravel or broken stone, or by driving piles.

516. **Platform Overturning Moments:** In all scales, when calculating moments tending to overturn or tip platforms, no distribution of vertical live loads shall be assumed. (See Section 2401.)

6. Particulars of Loading

601. **General:** All parts of scales shall be proportioned for the following loads and forces:

(a) Dead load.
(b) Live load.
(c) Impact, or dynamic effect of live load.
(d) Lateral forces.
(e) Longitudinal forces.

602. **Dead Load:**

(a) Unless provision is otherwise made in these specifications, the dead load shall be considered in the design of scales. The dead load shall be considered as the weight of all parts of the scale structure supported by the main lever load pivots and balanced out for the zero beam reading.

(b) The unit weights in Table 3 shall be used in computing dead load.

TABLE 3

UNIT WEIGHTS OF MATERIAL FOR USE IN COMPUTING DEAD LOADS

Material	*Weight per Cubic Foot*
Steel—Use handbook values or	490
Cast Iron	450
Timber, treated or untreated	60
Concrete, plain or reinforced	150
Pavement, other than wood block	150

603. Live and Dead Loads

(a) **Motor Truck Scales:** For the design of motor truck scales, the live load shall be assumed to be a five-axled vehicle whose wheel gage, axle spacing and axle loadings are as shown in Table 4.

Table 4

SCHEDULE OF LIVE LOADS FOR MOTOR TRUCK SCALES

Axle	*Axle Load (wheels spaced 72 in. apart, center to center) (pounds)*	*Distance center to center of following axle (inches)*
1	6,000	168
2	16,000	40
3	16,000	100
4	16,000	40
5	16,000	

The combined live and dead loads to be used in design of parts shall be as listed in Table 5 (see also Section 604).

Table 5

COMBINED LIVE AND DEAD LOADS TO BE USED IN THE DESIGN OF MOTOR TRUCK SCALES

Note 1.—The "corner load" is the greatest permissible combined live and dead load reaction at any main load pivot.

Note 2.—The "end load" is the greatest permissible combined live and dead load at the two main load pivots at the same end of the scale.

Platform Size (feet)	*Corner Load (pounds)*	*End Load (pounds)*	*Total Load (pounds)*
18 by 9	23,400	42,000	80,400
20 by 9	25,500	46,400	82,100
20 by 10	27,600	47,100	83,600
24 by 9	28,800	53,200	86,000
24 by 10	31,000	54,100	87,800
28 by 10	34,800	59,500	92,000
34 by 10	38,500	67,400	105,800
40 by 10	38,500	74,900	114,100

For special cases involving platform dimensions not given in the foregoing table, the corner, end and total load reactions used in design shall be those given for the next larger platform size. These data do not hold for scales whose nominal capacities exceed 70,000 lb.

(b) **Built-in Scales:** In built-in scales the design shall provide for two live loads totaling the capacity of the scale, spaced apart equal to the shortest distance between two main lever load pivots, so located on the deck and so relatively proportioned as to cause the greatest stress in the member being designed. The maximum value of the greater of the two live loads shall be

$$L = 0.75\, W - 0.25\, D$$

and the minimum

$$L = 0.50\, W$$

wherein W is the scale capacity

D is the dead load.

(c) **Self-contained and Portable Scales:** In self-contained and portable scales, the design shall provide for a condition of live loading consisting of two equal loads totaling the scale capacity, spaced apart equal to the diagonal distance between main lever load pivots and so located as to cause greatest stress in the member being designed. Except in instances where, for some special reason, the design includes dead load features not regularly catalogued or comprised in the model of scale, the dead load may be neglected.

604. **Impact:** In the design of scales covered by these specifications, when stresses are used not greater than the "Working Stresses", Table 2, Section 5, herein, no increase need be made to vertical live loads, or need any other allowance be considered to provide for the effects commonly included under the general term "Impact".

605. **Lateral Forces.**

(a) **Motor Truck and Built-in Scales:** The platforms of motor truck and built-in scales shall be designed for a lateral live load concentrated at the center of the span, equal to 20 per cent of the capacity plus 100 lb. per foot of span.

(b) **Self-contained and Portable Scales:** In self-contained and portable scales, provision shall be made for the effect of a lateral force of 1000 pounds and 500 pounds, respectively, acting in the plane of the deck and in a vertical plane through the transverse center line.

606. **Longitudinal Forces:**

(a) **Motor Truck and Built-in Scales:** In motor truck and built-in scales, provision shall be made for the effect of a longitudinal force of 10 per cent of the capacity of the scale, acting in the plane of the platform and in a vertical plane through the longitudinal center line.

(b) **Self-contained and Portable Scales:** In self-contained and portable scales, provision shall be made for the effect of a longitudinal force of 1000 pounds and 500 pounds, respectively, acting in the plane of the platform and in a plane through the longitudinal center line.

7. Scale Levers

701. **Limitation of Type:** Truss rods shall not be used in parts of the lever system except to stiffen levers laterally, or to prevent whipping and vibration due to impacting loads. Truss rods designed as parts of a lever structure to support vertically applied loads will not be permitted.

702. **Qualities of Castings:** Cast pieces used for levers shall not be warped. They shall be clean, smooth, uniform, and free from blisters, blowholes and shrinkage cracks.

703. **Machined Ways for Nose Irons:** In motor truck scales, levers that are to be equipped with nose irons shall have those portions of the lever ends receiving them machined for the full distance over which the nose irons are to move.

704. **Nose Iron Guides:** The guides for all nose irons shall be such that when one is moved for the purpose of adjustment, the pivot will be held parallel to its original position.

705. **Leveling Lugs:** In motor truck scales and built-in scales of the straight lever type, each lever shall be provided with leveling lugs for longitudinal alinement; for torsion levers, leveling lugs shall be provided on the pipe or torsion member for transverse alinement, and on the extension arm for longitudinal alinement. Each pair of lugs shall be spaced 11 inches. The leveling surfaces of each pair of lugs shall be finished to a common plane parallel to the plane through the knife-edges of the end pivots.

706. **Marking of Levers:** In motor truck scales, figures denoting the ratio of each lever shall be cast or otherwise permanently marked on the lever.

8. Pivots and Bearing Steels

801. **Material:** The material used for pivots and bearing steels in scales covered by these specifications shall be either—

(a) Special alloy pivot steel (S.A.E. 6195 or 52100), hardened to Rockwell C scale not less than 58, or

(b) Carbon steel (S.A.E. 1095), hardened to Rockwell C scale not less than 60.

802. **Design:** In motor truck scales and built-in scales, all pivots shall be so designed and manufactured that the included angle of the sides forming the knife-edge will not exceed 90 degrees, and the offset of the knife-edge as referred to the center line of the pivot will not exceed 10 per cent of the width of the pivot for "machined in" pivots and 15 per cent of the width of the pivot for "cast in" pivots.

803. **Fastening:** All pivots shall be firmly fastened in position without swaging or calking.

804. **Continuous Contact:** All pivots shall be so mounted as to secure equal and continuous contact of the knife-edges with their respective bearings for the full length of the parts designed to be in contact; in loop bearings, the knife-edges shall project slightly beyond the bearings in the loops.

805. **Position:** In any lever, pivots shall be so mounted that—

(a) Each knife-edge will be maintained in a horizontal plane under any load within the capacity of the scale.

(b) A plane bisecting the angle of a knife-edge will be perpendicular to the plane through the knife-edges of the end pivots.

(c) In motor truck and built-in scales, the actual distance between the end knife-edges of any lever will not differ from the nominal distance by more than 1/64 inch per foot.

(d) The knife-edges in any lever will be parallel.

806. **Support for Projecting Pivots:** The reinforcing on the levers to support projecting pivots shall be tapered off to prevent accumulation of dirt next to the pivots and to provide proper clearances.

807. **Design of Bearings:** Bearing steels and the parts supporting or containing them shall be so applied to the mechanism that permissible movement of the platform will not displace the line of contact between any bearing and the opposing pivot.

808. **Interchangeability of Bearing Steels:** All bearing steels of the same nominal dimensions or parts identification shall be interchangeable or mounted in interchangeable bearing blocks. The interchangeable part shall be securely mounted in the part containing it.

809. **Finish of Bearing Steels:** The bearing surfaces shall be brought to a smooth, true and accurate finish to insure continuity of contact with opposing pivots.

9. Nose Irons

901. **Design:** Nose irons shall be so constructed that:

(a) In motor truck scales, they will be positioned by means of adjusting screws of standard size and thread.

(b) They will be retained in position by means of screws or bolts of standard size and thread.

(c) The surfaces of nose irons intended to be in slidable contact with the levers will be true, so as to secure an accurate fit in or on the levers. For motor truck scales, such surfaces shall be machined.

(d) When adjustments are made, the knife-edge will be held parallel to its normal position.

902. **Screws and Bolts:** Adjusting and retaining screws and bolts shall be made of a corrosion-resistant material.

903. **Retaining Device:** A device for retaining each nose iron in position shall be provided, and shall be so designed and constructed that:

(a) It will be independent of the means provided for adjustment.

(b) It will not cause indentations in the lever.

(c) Loads applied to the scale will not cause tension in the retaining bolts.

(d) The nose iron will remain in position when the retaining device is released.

904. **Marking of Position:** The position of each nose iron, as determined by factory adjustment, shall be accurately, clearly, and permanently indicated by well defined marks on the lever and nose iron, which meet on a common line.

10. Loops and Connections

1001. **Design Proportion:** Loops which form bearings for projecting pivots may be of any type, provided the clearance between the enclosed pivots and the body of the loop is at least one-fourth inch.

1002. **Length:** All loops of like connections shall be of the same length.

1003. **Vertical Adjustment:** Means for vertical adjustment shall be provided between the lever system and the beam, which will permit independent leveling of the shelf lever when one is used. When no shelf lever is used, the connection to the beam shall be adjustable. Screw adjustments shall be provided with lock nuts or equivalent device.

11. Lever Fulcrum Stands

1101. **Qualities of Castings:** Castings for lever stands shall be clean, smooth, uniform, and free from blisters, blowholes and shrinkage cracks.

1102. **Proportions:** Lever stands shall be so designed, constructed and installed that, under any practical condition of loading the resultant force applied through the bearing will fall within the middle third of the length and width of the base.

1103. **Bases for Lever Stands:** The base of any lever stand shall be true within 1/32 inch to a plane perpendicular to a vertical line through the center of the knife-edge bearing carried by the upright portion of the stand.

1104. **Finish of Tops of Stands:** The top of any lever stand receiving a bearing steel, cap or block shall be finished smooth and shall be parallel to the base within 1/32 in.

1105. **Anchor Bolt Holes:** For built-in scales of the A-lever type, one anchor bolt hole 1.5 inches in diameter shall be provided in the base of each stand. In all other scales, two or more anchor bolt holes, 1.5 inches in diameter, shall be provided in the base of each stand unless other equally effective means for anchorage is provided.

12. Checks

1201. **Type:** The weigh-bridges, or platforms, of all scales shall be equipped with devices which effectively restrict motion in any horizontal direction, so designed and constructed as to withstand adequately the horizontal forces prescribed in Sections 605 and 606. For motor truck and built-in scales, if checks of either the rod or bumper type are used, they shall be adjustable.

13. Weigh-Beams and Accessories

1301. **Capacity to be Marked:** For scales not equipped with full-capacity weigh-beams, the permissible nominal capacity of the scale shall be explicitly and conspicuously marked on or near the beam.

1302. **Requirement for Nominal Capacity:** The nominal capacity as defined in Section 301–(b) shall not exceed the scale capacity.

1303. **Type of Beam:**

(a) **Motor Truck Scales:** Full-capacity weigh-beams shall be provided. The graduations on tare bars shall be as specified for the main bar. Tare bars shall not be furnished for beams of the registering type.

(b) **Other than Motor Truck Scales:** At the option of the purchaser, a full-capacity, weigh-beam, with or without tare bar, or a double or a single weigh-beam with counterpoise weights shall be provided.

1304. **Ratio:** A pivot and loop shall be provided at the beam tip. For other than motor truck scales, the ratio at the beam tip pivot shall be—

For built-in scales	500 or 1000
For self-contained scales	200 or 500
For portable scales	100

For all scales, the ratio to the beam butt pivot shall be plainly and permanently stamped on the beam.

1305. **Poise Stop:** In all scales, each beam bar shall be provided with a stop to prevent movement of the beam poise back of the zero notch or graduation.

1306. **Notches:** On main beams the notches shall not be spaced closer than six to the inch. Each notch shall be so made that when the pawl rests in it, a line projected from the center of the side of the notch nearer the zero graduation to the axis about which the pawl stem rotates will be perpendicular to that side of the notch.

(a) In motor truck scales, the value of each notch on the main beam shall be 1,000 pounds.

1307. **Pawl or Latch:** The tip of the pawl or latch shall be of the same width as the notches of the beam and shall be rounded so that a small amount of foreign material in the bottom of the notch will not prevent the poise from assuming its correct position when the pawl is dropped in the notch.

1308. **Projections or Recesses:** Poises shall be designed with the object of reducing to a minimum the number of projections and recesses that will retain foreign material.

1309. **Poise Bearings:** Each poise shall be constructed to move along its beam without side play. In full-capacity beams, the main poises shall be equipped with roller or other form of frictionless bearing.

1310. **Fractional Poises on Registering Beams:** The fractional poise on a registering beam shall be constructed to stop positively at each graduation and to prevent movement beyond the last graduation. In motor truck scales, the last registration of the fractional poise shall be 990 pounds, and in built-in and self-contained scales, 98 pounds or 95 pounds.

1311. **Operating Lever:** On registering beams, a substantial type of hand grip shall be provided to facilitate the registration of the weight. The natural operation of the registering mechanism shall not cause lateral displacement of the beam.

1312. **Receptacle for Weight Ticket:** On registering beams, means shall be provided to prevent placing the weight ticket in its receptacle in any position in which a weight can be registered different from that represented by the poise setting.

1313. **Balance Ball:** For motor truck scales, the position of the balance ball shall be vertically adjustable. For all scales, unless otherwise required by law or regulation, longitudinal movement shall be controlled by means of a self-contained, hand-operated screw, or other device, which will not require the ball to be rotated in making adjustments.

1314. **Poises and Weights:**

(a) **Material:** Counterpoise weights and the exterior shell of poises shall be made of corrosion-resistant alloys, steel, iron, brass, or any other metal or alloy of metals not softer than brass. Poises shall have no metal softer than brass making contact with the beam.

(b) **Movable Parts:** All movable elements forming a part of a poise shall be so constructed as not to be detachable without manifest mutilation of the poise. Set screws, if used to secure a poise at any point on a beam, shall not be removable.

(c) **Corrosion Protection:** Weights made of corrosive material, such as cast iron or steel, shall be protected from corrosion by the application of a durable chemical coating.

(d) **Surface and Form:** Weights shall be smooth, without sharp points or corners, and of such form that the minimum surface consistent with convenience of use will be exposed to wear or corrosion.

(e) **Adjusting Cavities:** All cavities for adjusting material shall be formed in the top or sides of counterpoise weights, and shall be of such form that the adjusting material will be permanently and securely retained. The adjusting material shall not project beyond the surface of the weight and, if in the top of the weight, the material closing the cavity shall be not more than 0.04 inch below the surface.

(f) **Marking:** All counterpoise weights shall be clearly marked with their nominal weight, i.e., 1 lb., 2 lb., etc., and also with the value they represent when used upon the scale for which they are intended.

(g) **Sealing:** After the weights are adjusted to their proper value, all caps or plugs closing adjusting cavities shall receive the impression of a seal, appropriate in character or design, to attest the factory adjustment, if made at the factory of the manufacturer; or, if readjusted elsewhere, the seal shall be such as to indicate when and under what authority the adjustment was made.

(h) **Counterbalance Weights:** If counterbalance weights are to be used, the lower end of the counterbalance hanger stem shall be threaded; a cup for the loose balancing material shall be screwed to the lower end of the stem; and each additional weight shall be provided with an elongated hole in the center through which the hanger stem may pass. No slotted counterbalance weights are to be used. When no counterbalance weights are necessary on top of the counterbalance cup, the cavity shall be closed by a cover secured in a positive manner. No counterbalance weights shall be used in any place in the scale except at the beam.

(i) **Tolerances:** The manufacturer's tolerances in excess or deficiency shall be no greater than the values in the following table.

TABLE 6

TOLERANCES ON NEW COUNTERPOISE WEIGHTS

(Avoirdupois System)

Weight (pounds)	*Ratio 100:1 and less than 1000:1* (grains)	*Ratio 1000:1 and over* (grains)
15	8.0	4.0
10	8.0	4.0
8	6.0	3.0
5	6.0	3.0
4	4.0	2.0
3	4.0	2.0
2	3.0	1.5
1	2.0	1.0
(ounces)		
10	2.0	1.0
8	1.0	0.5
5	1.0	0.5
4	1.0	0.5

1315. **Identification of Parts:** A serial number shall be legibly stamped on each complete weigh-beam.

1316. **Type Figures:** On type registering beams, type figures shall be made of material sufficiently hard that, under the designed conditions of use, the figures will not become battered or defaced. The figures shall be plain and raised sufficiently high to insure a clear impression upon the weight ticket or tape. They shall be so attached that they cannot become loosened or detached without a positive indication that the beam is out of order.

1317. **Beam Fulcrum Stands:** The upright portion of any beam fulcrum stand shall be so placed on the base that for any position of the beam in the normal weighing operation the line of resultant force through the fulcrum knife-edge will pass through the middle third of the length and width of the base.

(a) **Motor Truck Scales:** For motor truck scales the beam shall not be suspended. It shall be supported on a stand provided with compensating bearings.

1318. **Trig Loops:** The trig loop shall permit the vertical movement of the beam shown in Table 7.

TABLE 7

MINIMAL VERTICAL MOVEMENT OF WEIGH-BEAMS IN TRIG LOOPS

Distance from Fulcrum to Trig Loop	*Minimal Vertical Movement in Trig Loop*
Under 12 inches	0.4 inch
Over 12 inches, including 20 inches	0.5 "
Over 20 inches, including 40 inches	0.7 "
Over 40 inches	0.9 "

1319. **Beam Support:** In all scales, the beam fulcrum stand shall be securely fastened to a support sufficiently strong that deflection to an extent affecting the weighing performance cannot occur. If a wooden box is used for housing the weigh-beam, the shelf supporting the beam shall be independent of the box.

14. Anti-Friction Points and Plates

1401. Anti-friction contacts shall be used to limit longitudinal displacement between knife-edges and their bearings. They shall be smooth, hardened, and so designed as to provide contact at a point on the line of the knife-edge of the pivots. For motor truck and built-in scales they shall be of hardened steel.

15. Clearances

1501. The clearance around and between the fixed and live parts of the lever system of motor truck scales shall be at least ¾ in., and for built-in and self-contained scales the clearance shall be not less than ⅜ in. The total clearance between anti-friction points on levers and stands shall be not less than 1/16 in. nor greater than ⅛ in.

16. Factory Adjustments

1601. **Levers:** The design, workmanship and factory adjustment of the levers and beam shall be such that the proper ratio of the lever arms will be maintained.

17. Interchangeability

1701. Units or parts of units intended to be interchangeable with like units or parts in scales of the same design and manufacture, shall be identified on the scale drawings or in the subject-matter of the proposal in such manner as will clearly indicate the interchangeable parts, the manner of replacement, and the adjustments required, if any, after replacement.

18. Sensibility Reciprocal (SR)

1801. **Definition:** The sensibility reciprocal is the change in load required to turn the weigh-beam from a position of equilibrium in the center of the trig loop to a position of equilibrium at either limit of its travel.

19. Performance Requirements

1901. **Tolerances:** The tolerance in excess or deficiency for motor truck, built-in, self-contained and portable scales when tested upon the site of use and before being accepted as satisfactory weighing machines, shall be 0.10 per cent of the applied load consisting of test weights of known value; provided (1) the tolerance shall not be less than one-half the minimal beam graduation on the scale being tested; and (2) a purchaser may by stipulation in the purchase order require scales on the same condition of test to meet tolerances not less than one-half, respectively, of the tolerances given above before accepting delivery.

1902. **Sensibility Reciprocal:** For the same classes of scales and the same conditions of test stipulated in Section 1901, the sensibility reciprocal shall not exceed the value of the minimal beam graduation.

20. Location and Elevation

2001. **Location:** Motor truck, built-in and self-contained scales shall be so located that an adequate foundation and a straight approach in line with the scale platform and of a length in excess of that of the longest vehicle to be weighed can be provided.

2002. **Elevation:** The scale platform shall be raised to such an elevation that the drainage of surface water will be away from it and, unless space will not permit it, the approaches shall be level, or nearly level, and paved for a length equal to that of the scale platform.

21. Foundations

2101. **Material:** Scale foundations resting upon or extending into the ground shall be constructed of concrete. (See Section 515.)

2102. **Dimensions of Pit:** For motor truck and built-in scales, the size of the pit shall be such as to give a vertical clearance between the scale levers and the finished floor of the pit of not less than 2 ft., and a horizontal clearance between the face of the pit walls and the scale parts below the platform, or below the weigh-bridge girders, if any, and above the bases of the stands, or not less than 4 in. for motor truck scales and 1.5 in. for built-in scales.

2103. **Walls of Pit:** The walls of the pit shall have a thickness at the top of not less than 12 in. for motor truck scales, and not less than 8 in. for built-in scales.

2104. **Waterproofing:** When necessary, the pit shall be waterproofed.

2105. **Wall Batter:** All wall surfaces next to earth subject to freezing shall be constructed with a uniform batter of not less than 1 in. to the foot and as much more as necessary to permit the heaving of adjacent ground by frost action without disturbing the walls.

2106. **Pit Floors and Lever Stand Piers:** The concrete piers supporting the lever stands shall be not less than 9 in. deep, but shall in any case be carried to proper foundation. Their tops shall be above the floor of the pit a distance sufficient to prevent the accumulation of water under the bases of the stands. The floor of the pit may be designed as a mat footing of concrete, or as a simple floor not less than 4 in. thick. The pit floor shall, in all cases, be smooth, with a pitch to a common point of drainage, and free from pockets in which water will stand.

2107. **Anchor Bolts:** Anchor bolts, not less than ⅞ in. in diameter, threaded and with nuts and washers, shall be provided in the foundations for lever stands to match the bolt holes provided for securing the stands, and they shall extend into the concrete not less than 8 in.

2108. **Anchorage for Floating Levers:** A floating lever, that is, one exerting an upward pull at its fulcrum, shall be anchored to the foundation to resist not less than twice the upward pull produced at the fulcrum pivot by a capacity load on the scale.

22. Scale Beam House or Box

2201. **Scale Beam House or Box:** When the scale is not located in a building, the scale beam shall be adequately protected from the weather by being enclosed in a house or box. When a scale is located in a building, it shall, when necessary, be similarly protected from injury.

2202. **Design:** The minimum inside width of the scale house shall be 4 ft., and the minimum length shall be sufficient to allow the installation therein of the beam shelf and beam. It shall be provided with windows of such size and location as will give the weigher, when weighing, a clear and unobstructed view of the scale platform and approaches. The windows shall be glazed with clear glass or clear wire glass. If the beam is required to be boxed, the box shall be of such size as to suitably enclose the beam shelf and beam. It shall be provided with a hinged door, or doors, of such size and in such location as to give the weigher clear and unobstructed access to the beam.

2203. **Clearance:** A clearance of not less than 1 in. shall be provided between the inside of the scale house and the beam supports and shelf. The clearance between the edge of the platform and weighbeam pillar, beam box or scale house shall be sufficient to permit the normal functions of weighing the widest loads required to be handled.

23. Installation

2301. **Fastening of Stands:** After alining the stands, the anchor bolt holes in the castings shall be filled with cement, sulphur or other suitable material, and the anchor bolt nuts brought down tight.

2302. **Alinement:** All levers shall be level and connections plumb throughout the scale.

24. Platforms

2401. **Security Against Tipping:** All scale platforms shall be proportioned so that, for any possible application of the loads specified for different classes of scales in Section 6, no tipping can occur. (See Section 516.)

2402. **Timber:** In all scale platforms, timber shall not be used for floor beams, stringers, or in any members, except floor covering, required to take shearing or compressive stress perpendicular to the grain, or stress in transverse bending. Timber may be used for floor covering and, as required, for spiking or fastening strips for the floor covering. (See Sections 514 and 2409.)

2403. **Weigh-Bridges:** For motor truck and built-in scales, weigh-bridge girders, floor beams and stringers shall be made of steel conforming to American Railway Engineering Association Specifications for Steel Highway Bridges, Sections II and III.

2404. **Sections and Strength:**

(a) Weigh-bridge members shall be designed in accordance with Sections XIV and XV of the American Railway Engineering Association Specifications for Steel Highway Bridges, except as the permissible working stresses and loading conditions are modified by Sections 5 and 6 herein.

(b) **Motor Truck Scales:** In motor truck scale weigh-bridges, the section moduli of main girders shall be as shown in Table 8. A representative bill of steel for each size weigh-bridge is also shown in the table. The members listed in Table 8 have been calculated from the loading assumptions given in Table 4, and on the basis of 12 in. side overhang outside the center lines of main girders and 12 in. end overhang outside the centers of load bearings. Variation from the sizes given may result if other conditions of side and end overhang are actually used. Provision has been made for impact by using the working stresses given in Section 5.

2405. **Bracing:**

(a) **Built-in Scales:** Weigh-bridges for built-in scales ordinarily will require no bracing other than floor beams and corner plates.

(b) **Motor Truck Scales:** If the floor beams are mounted above the main girders, weigh-bridges of motor truck scales with solid floor construction or with transverse floor beams on 36-inch centers or less will require no lateral bracing. Otherwise bracing shall be designed for the forces in Section 605 - (a). The internal bracing members shall not be less than 3″ × 3″ × ¼″ angles.

(c) **Cross Frames:** Motor truck scale weigh-bridges with the floor beams mounted above the main girders shall be provided with end cross frames and at least one intermediate cross frame. If the floor beams are internally framed and the weigh-bridge otherwise adequately braced, the end and intermediate cross frames may be omitted.

2406. **Fabrication and Assembly:**

(a) **Motor Truck Scales:** The weigh-bridges for motor truck scales shall, when practicable, be assembled and riveted up complete in the shop. When field assembly is necessary, the parts shall be properly assembled in the shop and match-marked. Connecting holes shall be reamed to fit.

(b) **Built-in Scales:** The weigh-bridges for built-in scales shall be assembled and riveted, or bolted up in the shop under proper inspection. When delivered, they shall be square and the surfaces receiving the platform bearings shall be parallel.

2407. **Platform Bearings:** In motor truck scales and built-in scales, the tops of platform bearings contacting the weigh-bridge girders shall be finished to within 1/32 inch of a true plane. These tops shall be provided with bolt holes of sufficiently large diameter to allow for the transverse and longitudinal adjustment necessary to secure proper alinement of parts.

TABLE 8

REPRESENTATIVE BILLS OF STEEL FOR WEIGH-BRIDGES FOR MOTOR TRUCK SCALES

Plank floor of 4 in. nominal thickness

Member and Mark	Platform Size in Feet							
	18x9	20x9	20x10	24x9	24x10	28x10	34x10	40x10
Main Girder (B-1)	59.6* 2-16″ WF at 36 lb.	76.3* 2-18″ WF at 47 lb.	83.6* 2-18″ WF at 47 lb.	116.3* 2-21″ WF at 59 lb.	127.2* 2-21″ WF at 63 lb.	172.8* 2-24″ WF at 74 lb.	244.8* 2-27″ WF at 98 lb.	319.0* 2-30″WF at 116 lb.
	1296 lb.	1880 lb.	1880 lb.	2832 lb.	3024 lb.	4144 lb.	6664 lb.	9280 lb.
Floorbeam (B-2)	4-10″ WF at 21 lb. 588 lb.	4-10″ WF at 21 lb. 588 lb.	5-10″ WF at 21 lb. 840 lb.	5-10″ WF at 21 lb. 735 lb.	5-10″ WF at 21 lb. 840 lb.	6-10″ WF at 21 lb. 1008 lb.	7-10″ WF at 21 lb. 1176 lb.	8-10″ WF at 21 lb. 1344 lb.
Inside Stringer (B-3) 2-6″ I at 12.5 lb.	450 lb.	500 lb.	500 lb.	600 lb.	600 lb.	700 lb.	850 lb.	1000 lb.
Outside Bracket (B-4) 8″ WF at 17 lb.	10- 170 lb.	12- 204 lb.	12- 204 lb.	14- 238 lb.	14- 238 lb.	16- 272 lb.	20- 340 lb.	22- 374 lb.
Outside Stringer (C-1) 2-8″ C at 11.5 lb.	414 lb.	460 lb.	460 lb.	552 lb.	552 lb.	644 lb.	782 lb.	920 lb.
Coping Steel 3″ x 3″x $\frac{3}{8}$″ < at 7.5 lb.	405 lb.	435 lb.	450 lb.	495 lb.	510 lb.	570 lb.	645 lb.	750 lb.
Total Shapes	3323 lb.	4067 lb.	4334 lb.	5452 lb.	5664 lb.	7338 lb.	10457 lb.	13668 lb.
Fastenings, 5%	166 lb.	204 lb.	217 lb.	273 lb.	283 lb.	367 lb.	528 lb.	683 lb.
Total Metal	3489 lb.	4271 lb.	4551 lb.	5725 lb.	5947 lb.	7705 lb.	10985 lb.	14351 lb.

* Required section modulus, one girder.

TABLE 8 (continued)

REPRESENTATIVE BILLS OF STEEL FOR WEIGH-BRIDGES FOR MOTOR TRUCK SCALES

Concrete deck; 6-in. slab

Member and Mark	Platform Size in Feet							
	18x9	20x9	20x10	24x9	24x10	28x10	34x10	40x10
Main Girder* (B-1)	2–16″ WF at 36 lb. 1296 lb.	2–18″ WF at 47 lb. 1880 lb.	2–18″ WF at 47 lb. 1880 lb.	2–21″ WF at 59 lb. 2832 lb.	2–21″ WF at 63 lb. 3024 lb.	2–24″ WF at 74 lb. 4144 lb.	2–27″ WF at 98 lb. 6664 lb.	2–30″ WF at 116 lb. 9280 lb.
Floorbeam (B-2)	4–10″ WF at 23 lb. 644 lb.	4–10″ WF at 23 lb. 644 lb.	4–10″ WF at 23 lb. 736 lb.	5–10″ WF at 23 lb. 805 lb.	5–10″ WF at 23 lb. 920 lb.	6–10″ WF at 23 lb. 1104 lb.	7–10″ WF at 23 lb. 1288 lb.	8–10″ WF at 23 lb. 1472 lb.
Edge Irons (C-1) 2–6″ C at 8.2 lb.	295 lb.	328 lb.	328 lb.	394 lb.	394 lb.	459 lb.	558 lb.	656 lb.
End Irons (C-2) 2–6″ C at 8.2 lb.	148 lb.	148 lb.	164 lb.	148 lb.	164 lb.	164 lb.	164 lb.	164 lb.
Reinforcing Rods Longitudinal Lateral	½″ rounds at 22 264 lb. 99 182 lb.	0.668 lb. 22 294 lb. 110 202 lb.	25 334 lb. 110 220 lb.	22 353 lb. 132 243 lb.	25 401 lb. 132 265 lb.	25 468 lb. 156 313 lb.	25 568 lb. 188 376 lb.	25 668 lb. 220 441 lb.
Tie Rods 3 - ½″ rounds at 0.668 lb.	18 lb.	18 lb.	20 lb.	18 lb.	20 lb.	20 lb.	20 lb.	20 lb.
Coping Steel 3″x3″x⅜″ ∠ at 7.5 lb.	405 lb.	435 lb.	450 lb.	495 lb.	510 lb.	570 lb.	645 lb.	750 lb.
Shapes and Rods	3252 lb.	3952 lb.	4132 lb.	5288 lb.	5598 lb.	7242 lb.	10283 lb.	13451 lb.
Fastenings, 5%	163 lb.	198 lb.	207 lb.	264 lb.	280 lb.	362 lb.	514 lb.	673 lb.
Total Metal	3415 lb.	4150 lb.	4339 lb.	5552 lb.	5878 lb.	7604 lb.	10797 lb.	14124 lb.

* Required section modulus, one girder, same as shown in table covering plank floor.

2408. **Deck:** The deck or floor shall be designed so that, without exceeding the permissible stresses, it will support and distribute the capacity load and incidental forces when applied as described in Section 6, and so as to produce the maximum stress in any part of the floor.

2409. **Flooring:** The flooring material shall resist wear, shall under all weather conditions provide traction to power-driven vehicles, and shall be susceptible of being waterproofed. If timber is used, its quality shall be at least No. 1 Common dimension, treated with a preservative.

2410. **Self-contained and Portable Scales:** The platforms of self-contained and portable scales shall be entirely of metal, or a metal frame with a hardwood center panel, and shall be so designed that, without exceeding the permissible stresses, the loads and forces prescribed in Section 6, when so applied as to produce maximum stress, can be sustained.

25. Light, Drainage and Ventilation

2501. **Light:** Proper lighting of the scale weigh-beam and scale platform shall be provided.

2502. **Drainage:** Adequate drainage for scale pits shall be provided and maintained.

2503. **Ventilation:** All scale pits shall be ventilated to meet the needs of each particular case, the object being to minimize the amount of moisture in the air in the pit and so to retard rusting of scale parts and structural steel.

26. Entrance to Scale Pit

2601. **Location:** For built-in scales, the entrance to the scale pit for inspection purposes shall be through the platform of the scale, foundation wall, or the neck of the scale pit; for motor truck scales, the entrance to the scale pit shall be through the foundation wall or neck of the pit.

27. Protection from Corrosion

2701. The finish and treatment of all surfaces shall be such as to insure good appearance and satisfactory resistance to corrosion. The surface treatment shall be durable and appropriate for the intended uses.

Appendix D

(6) BIBLIOGRAPHY ON SUBJECTS PERTAINING TO YARDS AND TERMINALS APPEARING IN CURRENT PERIODICALS

Compiled by E. E. R. Tratman

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Montreal—Marine Review, 1935, August, page 16—Shipping Register and World Ports, 1934, September 8—Canadian Railway and Marine World, 1935, May, page 227; June, page 289.

Newark—Shipping Register and World Ports, 1934, September 8.

New Jersey (South Jersey)—Shipping Register and World Ports, 1934, September 8.

New York; new steamship piers 1000 ft. long—Engineering News-Record, 1935, May 30, page 789—Marine Review, 1935, August, page 31.

New York; terminal for handling oil products—Marine Review, 1935, September, page 20.

Oswego—coal handling plant; Delaware, Lackawanna and Western R. R.—Shipping Register and World Ports, 1934, September 8—Marine Review, 1935, July.

Panama Canal; terminal facilities—Marine Review, 1935, May, page 29.

Parkeston Quay, England; new trestle type of concrete quay, with cargo sheds, railway station, and accommodations for car ferries and steamers—Engineering News-Record, 1935, August 22, page 265.

Philadelphia—Shipping Register and World Ports, 1934, September 8.

Prince Rupert—Canadian Railway and Marine World, 1935, April, page 179.

Portland, Me.—Shipping Register and World Ports, 1934, September 8.

Quebec—Canadian Railway and Marine World, 1935, June, page 281.

St. John, N. B.; new port facilities—Canadian Railway and Marine World, 1934, December, page 545; 1935, April, page 175.

St. Joseph—Shipping Register and World Ports, 1934, September 8.

San Diego—Marine Review, 1935, September, page 14.

San Francisco—Marine Review, 1935, May, page 12.

Seattle; sea wall and waterfront street with railway tracks—Engineering News-Record, 1934, November 8, page 579—Shipping Register and World Ports, 1934, September 8.

Texas City—Shipping Register and World Ports, 1934, September 8.

Toronto; harbor and traffic—Canadian Railway and Marine World, 1934, September, page 410; October, page 450; 1935, September, pages 427 and 432—Shipping Register and World Ports, 1934, September 8.

Trenton—Shipping Register and World Ports, 1934, September 8.

Vancouver; port facilities—Canadian Railway and Marine World, 1934, August, page 364—Shipping Register and World Ports, 1934, September 8.

Victoria—Canadian Railway and Marine Review, 1935, April, page 179.

Banana dock; London; shed and warehouse with conveyor equipment for unloading steamer—The Engineer (London), 1935, August 23, page 188.

Car ferry—bridge supersedes car ferry between islands of Denmark—Engineering News-Record, 1935, June 13, page 841.

Car ferry—Dover, England, to Dunkerque, France; Southern Rý. (England)—The Engineer (London), 1935, March 15, page 275; April 26, page 436; May 17, page 513—Marine Review, 1934, September, page 12.

Car ferries; port facilities—A.R.E.A., Proceedings, 1935, page 71.

Car ferry; on Yangtse Kiang River, China; Nankin-Pukow—The Engineer (London), 1934, September 14, page 255.

Car ferry—Seatrain Lines; Hoboken to New Orleans; approved by Interstate Commerce Commission—Railway Age, 1935, February 16, page 279.

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Channels at ports; width and depth—A.R.E.A., Proceedings, 1935, page 68.

Coal barges—New York harbor; Pennsylvania R. R.—Marine Review, 1935, August, page 24.

Coal handling plant—loading steamers at Oswego; Delaware, Lackawanna and Western R. R.—Marine Review, 1935, July, page 32.

Coal piers—A.R.E.A., Proceedings, 1935, page 70.

Coordination of facilities—A.R.E.A., Proceedings, 1935, page 68.

Free port developments in the United States—American Association of Port Authorities, Proceedings, 1935—Shipping Register and World Ports, 1935, September 21.

Grain elevators and car yards—A.R.E.A., Proceedings, 1935, pages 66 and 71.
Harbors; structures and facilities—A.R.E.A., Proceedings, 1935, page 236.
Mechanical handling—A.R.E.A., Proceedings, 1935, page 69.
Oil and gasoline docks—A.R.E.A., Proceedings, 1935, page 70.
Ore docks; list and description of docks on the Great Lakes—A.R.E.A., Proceedings, 1935, pages 71 and 228.
Piers; freight piers; fender construction—A.R.E.A., Proceedings, 1935, pages 69, 71, 222 and 1044.
Piers; fire protection—Engineering News-Record, 1934, September 27, page 415—American Association of Port Authorities, Proceedings, 1934.
Piles; resistance to marine borers—A.R.E.A., Proceedings, 1935, page 487.
Port and terminal charges; uniform charges regulated by law—Railway Age, 1935, April 20, page 621; July 6, page 26; August 10, page 190—Report of Board of Engineers for Rivers and Harbors, U. S. War Department, 1934—Houston Port Book (Houston Port Commission), 1935, May.
Railway docks, England; competition between railway and private docks—The Engineer (London), 1935, April 5, page 357.
Rail terminals at ports; trackage—A.R.E.A., Proceedings, 1935, page 72.
Roads at ports; paved roadways and driveways—A.R.E.A., Proceedings, 1935, page 72.
Scales; track scales at ports—A.R.E.A., Proceedings, 1935, page 69.
Self-unloading steamers—World Ports, 1931, December, page 96—Marine Review, 1935, May, page 15—Black Diamond, 1935, June 8, page 25—Canadian Railway and Marine World, 1935, September, page 432.
Warehouses; provided at ports—A.R.E.A., Proceedings, 1935, page 71.

(E) COAL HANDLING

Aerial tramway; Anchor Coal Co.; Highcoal, W. Va.—Coal Age, 1935, April, page 151.
Coal breaker; Kehoe-Berge mines, Duryea, Pa.; only two tracks under breaker for loading eight sizes of coal—Coal Age, 1935, October, pages 383, 385, 387.
Car dumpers for coal handling—(see "Car dumpers" under "C-Freight Terminals" hereof).
Coal barges—Pennsylvania R. R. for New York harbor—Marine Review, 1935, August, page 24.
Coal breakage; reducing breakage in car dumpers—Marine Review, 1935, September, page 34.
Coal handling plant—Western Maryland Ry.—Iron Age, 1927, October 27.
Coal handling plant—Delaware, Lackawanna and Western R. R., Oswego; car dumper and belt conveyor—Marine Review, 1935, April, page 59; July, page 32.
Coal handling plants; review of various types—A.R.E.A., Proceedings, 1936.
Coal piers; size and equipment—A.R.E.A., Proceedings, 1935, page 70.
Coal sorting plant—Southern Ry. (England)—The Engineer (London), 1935, April 19, page 411.
Coal steamer or collier; ocean-going steamer with self-unloading equipment—Black Diamond, 1935, June 8, page 25—(see also "Self-unloading steamer" under "D-Rail-and-Water Terminals" herein)
Coal storage; Toronto, Ont.—Canadian Railway and Marine World, 1935, September, page 432.
Coal transfer plant; rail-and barge; Louisville—Black Diamond, 1935, July 6, page 26.
Culm bank loader; Righter Bank, Mt. Carmel, Pa.; conveyor loading to cars—Coal Age, 1935, January, pages 28 and 29.
Tipple; Crapo Mine, New Lathrop, Mich.—Coal Age, 1934, November, pages 411, 414 and 426.
Tipple; strip pit, Duquoin, Ill.; eight tracks—Coal Age, 1935, May, pages 197 and 200.
Tipple; Naomi Mine, Fayette City, Pa.; for delivery of coal to rail and river; five tracks under tipple—Coal Age, 1934, October, pages 377-379.
Tipple; Puritan Mine, Denver, Colo.; six tracks with two box car loaders—Coal Age, 1935, January, pages 16-18.
Tipple; Renton Mine, Renton, Pa.; four sizes of coal delivered on separate tracks—Coal Age, 1935, January, pages 10, 12 and 15.
Tipple; Van Lear Mine, Van Lear, Ky.; five tracks—Coal Age, 1935, October, pages 413-416.

REPORT OF COMMITTEE XIII—WATER SERVICE, FIRE PROTECTION AND SANITATION

R. C. Bardwell, *Chairman;*
W. M. Barr,
R. W. Chorley,
R. E. Coughlan,
W. L. Curtiss,
J. H. Davidson,
B. W. DeGeer,
R. N. Foster,
C. H. Fox,
W. P. Hale,
J. P. Hanley,
R. L. Holmes,
A. W. Johnson,
H. F. King,
C. R. Knowles,
J. J. Laudig,
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Ray McBrian,
M. E. McDonnell,
H. L. McMullin,
R. H. Miller,
E. R. Morris,
A. B. Pierce,
W. A. Radspinner,
O. T. Rees,
Owen Rice,
C. P. Richardson,
E. M. Grime, *Vice-Chairman;*
H. L. Roscoe,
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H. E. Silcox,
D. A. Steel,
R. M. Stimmel,
C. P. Van Gundy,
H. W. Van Hovenberg,
R. E. Wachter,
J. C. Wallace,
J. B. Wesley,
A. E. Willahan,
J. B. Young,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith its report covering the following subjects:

(1) Revision of Manual (Appendix A). It is recommended that the material incorporated herein with the changes and additions be adopted for publication in the Manual.

(2) Relation of railway fire protection equipment to municipal and privately owned waterworks. Progress in study—no report.

(3) Use of phosphates in water treatment. Progress in study—no report.

(4) Cause of and remedy for pitting and corrosion of locomotive boiler tubes and sheets, with special reference to status of embrittlement investigations (Appendix B). Progress report.

(5) Value of water treatment with respect to estimating and summarizing possible savings effected. Progress in study—no report.

(6) Types of lime and soda ash equipment in water treatment (Appendix C). Final report.

(7) Methods for analysis of chemicals used in water treatment. Progress in study—no report.

(8) Progress being made by Federal or State authorities on regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR. Progress in study—no report.

(9) Water conditions affecting the extension of locomotive washout periods (Appendix D). Final report.

(10) Clarification and disinfection of small railway drinking water supply. Progress in study—no report.

The Committee on Water Service, Fire Protection and Sanitation,
R. C. Bardwell, *Chairman.*

Bulletin 383, January, 1936.

Appendix A

(1) REVISION OF MANUAL

E. M. Grime, Chairman, Sub-Committee; R. E. Coughlan, B. W. DeGeer, R. N. Foster, J. P. Hanley, H. F. King, C. R. Knowles, J. J. Laudig, O. E. Mace, R. H. Miller, E. R. Morris, W. A. Radspinner, Owen Rice, J. A. Russell, H. E. Silcox, R. M. Stimmel, J. B. Wesley.

Your Committee has made a thorough review of the Manual and Supplements, and presents herewith its report as follows:

DEFINITIONS (Page 873)

After a careful study of the definitions, your Committee recommends that the following definitions now in the Manual be deleted:

Air Compressor
Boiler
— Locomotive Type
— Return Tubular
— Vertical
Blow Off
— Pipe Line
Control Panel
Dam
Drop
Dry Steam
Engine, Two Cycle
— Four Cycle
— Gas
— Gasoline
— Internal Combustion
— Oil
Evaporation
Float Switch
Hardness, Permanent
— Temporary
Hydrant, Fire
Hoop
Interception
Lead Pot
Lime, Hydrated
Meter, Venturi
Motors, Slip Ring
— Squirrel Cage
— Synchronous
Outlet Pipe
Pipe, Universal
— Bend (or Elbow)
— Cap
— Coupling
— Intake
— Joint, Bell and Spigot
— Flanged
— Plug
— Reducer
— Sleeve
— Tee
— Vise
— Y
Pump, Vertical Steam
— Valve, Ball
— Clapper
— Rubber
— Wing
Quicklime
Reagent
Saturated Steam
Seepage
Soda Ash
Sodium Aluminate Solution
Solids, Incrusting
— Non-Incrusting
Starting Torque
Steel
Suction
Sulphate of Alumina
— Iron
Tank Capacity
— Spout
— Tower
— Valve
Valve, Float
— Foot
— Gate
Water Main Cleaner
— Treatment
Well, Bored
— Drilled
— Rotary Drilled
— Driven
— Pumping Head
— Starting Head
— Intake
Wet Steam
Windmill
Wrench, Chain Pipe
— Stillson Pipe
Wrought Iron
Zeolite Water Softener

It is the recommendation of your Committee that the following definitions pertaining to water treatment and sanitation be included in the Manual:

Blow Down—The act of letting water out of the boiler for the purpose of carrying out sediment, to reduce the concentration of dissolved solids or for both purposes.

Deodorant—A substance of liquid or crystal form used to destroy or neutralize odors.

Disinfectants—Substances in liquid or powdered form having power to destroy germs or insects on contact, some being insecticides, some only germicides, and others with both powers.

Fumigant—A substance released in closed spaces in gaseous forms for destruction of germs or insects.

Formalin—An aqueous solution containing approximately 40 per cent of formaldehyde —used as a disinfectant.

Germicide—A gas, liquid, or powder, having power to destroy germs.

Insecticide—A substance used for the destruction of insects.

Liquor Cresolis—A solution composed of cresol ("straw-colored carbolic acid") and linseed-oil-potash solution in equal parts, used as a disinfectant.

Phenol Coefficient—The power of disinfectants, under certain conditions to kill typhoid fever germs as compared to carbolic acid power under the same conditions.

GENERAL PRINCIPLES OF WATER SERVICE (page 885)

Eliminate material under "Quantity" and "Quality" and substitute the following:

The quantity should at all times be sufficient to meet ordinary peak load demands, when supplemented by a reasonable amount of local storage, properly distributed. For emergency demands during short periods, such as for fire-fighting purposes, extraordinary traffic requirements, etc., the supply should be made adequate by judicious manipulations of storage using booster pumps or other means.

The quality should be satisfactory for the purposes intended. For potable uses it must meet the requirements both chemically and bacteriologically of the U. S. Treasury Department for water used in interstate traffic, and the facilities and personnel must be such as to insure no impairment of quality at any time. For steaming purposes the supply must be such as to reduce to a practical minimum all tendencies to cause scaling, corrosion, pitting, foaming or leaking of equipment. Raw water having these undesirable characteristics should be properly conditioned.

SUPPLY—SOURCE (page 886)

In the fourth paragraph, eliminate the second sentence, beginning with the words "Wherever possible" and substitute the following:

Storage of this kind may be provided by constructing dams in streams or valleys where water shed conditions are favorable. Where reservoirs of considerable size are contemplated, a thorough engineering survey of the location should be made. This study should include test hole borings, rainfall and runoff data, as well as a topographical survey of the water shed. The dam should be made of the most suitable materials considering local conditions and should be provided with carefully designed spillway capacity. The survey should also indicate that public and private property rights can be secured, and that the costs are not excessive for the benefits derived from this source of supply.

For discussion on Impounding Reservoirs, see pp. 915–919 inclusive, 1929 Manual.

QUALITY OF WATER—METHOD OF TREATMENT (page 919)

Add the following after the 5th paragraph:

Other chemicals used in the treatment of water include the following: barium compounds, caustic soda, ferrous sulphate, ferric salts, sodium phosphate salts, sodium aluminate, sulphate of alumina, tannins, and proprietary boiler compounds.

STORAGE (page 65, Bulletin 327)

Eliminate fourth paragraph and table of storage recommended on same page.

PUMPING PLANTS—BUILDINGS (pages 915 and 951)

Eliminate material under Pump Houses, page 915, and that under Heating Water Station Buildings, page 951, and substitute the following:

The water supply of a railroad is such an important facility that it is usually desirable to house the mechanical equipment required for this service in substantial buildings, generally of fireproof construction.

The size of the building will depend upon the nature of the equipment to be used. The foundations should be of concrete extending to a point at least six inches above the ground line. A concrete floor provided with a suitable drain is desirable. For the larger and more important plants, the walls should be of brick with sufficient windows to afford adequate lighting of the interior. Smaller and less important plants may be of frame construction. In cold climates the interior of pump houses should be ceiled or other insulating material used to prevent freezing, and where conditions permit, heating facilities should also be provided. These buildings may be heated by steam, electric current, or stoves, depending upon their locations. Small well constructed pump houses, at points where pumps are automatically operated by electric power, can sometimes be heated automatically with electricity at nominal cost. Suitable ventilators should be installed. Where conditions permit, artificial lighting facilities should be provided.

In southern climates, where protection against freezing is not a factor, frame buildings covered with galvanized iron will usually suffice for the small and less important plants.

All buildings housing deep well pumps should have a derrick frame over the well extending from 20 to 35 feet above the roof of the building. This frame should rest directly on the building foundations.

The use of indirect heating to prevent ice accumulation in water tanks instead of direct heating by coils immersed in the water or steam injected into same should be considered.

The use of frost-proofing materials and the installation of sealed drainage in water column pits to prevent the inflow of cold air through the drains would, in many cases, benefit the operation of the water columns.

Adequate drainage arrangements should be provided.

STEAM EQUIPMENT (page 887)

Eliminate last paragraph and charts on pages 888, 889, 890.

DEEP WELL EQUIPMENT (page 892)

Delete this material and substitute the following:

Each type has its respective advantages or disadvantages over others. To insure reliability and greatest overall economy, individual conditions should be thoroughly analyzed.

The most common types are the deep well reciprocating pump, the deep well centrifugal or turbine pump, and the air lift. When considering the relative merits of the different methods of deep well pumping, thought should be given to the following features:

Character of the water
Capacity of source of supply
Water demand
Pumping head
First cost of complete installation of equpiment
Useful life of equipment
Reliability
Flexibility
Efficiency
Cost of operation

Deep well reciprocating pumps are made in single plunger, single acting type; single plunger, double acting type; double plunger, single acting type; and triple plunger, single acting type.

When the water contains an appreciable amount of sand or gritty material the leather and valves of this type of pump soon require renewal making the maintenance cost comparatively high. These pumps will give satisfactory service at depths up to 300–400 feet, but at the greater depths the weight of rods requires large power heads and the delivery is limited to relatively small amounts. This types of positive acting pump is the most flexible over a medium range of pumping yields with the least variation in pumping efficiency.

Deep well turbine pumps with their close clearances are not suitable where the water carries gritty material which will cause excessive wear, but for clear water and moderate depths they usually show the highest efficiency for a specific case of fairly constant conditions. They are suitable for large or small yields. Being placed in the well at or below the water line, with the exception of a long shaft operated at high speed which must be kept in accurate alinement and also the necessity of periodic removal for repairs, this type has most of the advantages and few of the disadvantages of the ordinary centrifugal pump.

Air lift pumping equipment, having no working parts, is not affected to any large extent by gritty materials in the water and can be satisfactorily applied to all depths where the available submergence varies from 40 to 55 per cent. Its efficiency is low and in most cases an auxiliary pump is required to elevate the water for storage or to provide high working pressure for fire protection or other purposes. It can be used at depths where no other types of well equipment is practicable, although in case of very deep supplies several stages may be necessary to reduce the starting pressure to a reasonable working basis. This type may be used in holes which are so out-of-plumb as to preclude the possibility of using other pumping equipment and is limited in operating depth only by the capacity of the compressor available. If a single well will not furnish the water required, other wells at a moderate distance, governed by the friction in the air pipe, may be operated by piping the air from the central compressor station. For a given diameter of well the air lift will produce the largest yield. The aerating effect obtained by the use of this pumping method is sometimes advantageous for removal of iron or other impurities in natural waters.

Under average conditions the maintenance cost of an air lift system will be the lowest and that of a reciprocating system the highest. For average conditions the turbine pump usually works out satisfactorily. Attendance costs are practically the same in each case. Either system can be operated automatically, if desired.

CENTRIFUGAL PUMPS (page 893)

Eliminate all this material and substitute the following:

CENTRIFUGAL PUMPS

Centrifugal pumps may be divided into two general classes, Turbine and Volute Types.

The turbine pump has a circular casing and diffusion vanes. These diffusion vanes are provided with gradually enlarged passages, the function of which is to reduce the velocity of the water leaving the impeller and transform this velocity into pressure head. The turbine pump is adapted to a wide range of heads, depending on the number of stages and the design used. There may be little difference in efficiency at various heads. The term "Turbine" is usually applied to multi-stage vertical pumps for deep wells, the head per stage varying from ten to 30 feet, depending upon the size and design of the pump.

The volute pump has no diffusion vanes, but the casing is of the spiral type which gradually reduces the velocity of the water as it flows from the impeller to the discharge pipe. This pump may be of the single-stage or multi-stage, single-suction or double-suction, open or enclosed impeller type.

Volute pumps of the open impeller design are suitable for the pumping of large amounts of liquid at comparatively low heads. The clearance spaces in this open design permit handling debris laden liquid such as sewage or land drainage.

With the closed impeller design the clearances are reduced to the minimum so that even a single-stage pump may show good efficiency at heads up to 300 feet or more, without excessive speed. For greater heads such as for fire pressure or other requirements, multi-stages may show better efficiency. The double-suction design with the impeller drawing water from both sides is theoretically balanced, but slight variations in the castings may destroy the balance, making it desirable to take care of radial and end thrust in one bearing of the ball type.

Manufacturers of centrifugal pumps are able to so vary the design of the impeller and casing as to produce efficiencies as high as 90 per cent under widely varying heads.

ADVANTAGES OF CENTRIFUGAL PUMPS

Low initial cost.

Low maintenance cost.

Practically noiseless in operation.

Skilled labor for operation unnecessary.

Failure to open a valve or the sudden closure of the valve on the discharge will not immediately damage the pump.

Minimum floor space required.

The open impeller type is particularly adapted for handling muddy or sandy water with minimum injury to working parts.

Can be used in series more satisfactorily than any other type of pump.

They are non-pulsating and do not cause water hammer.

They are particularly adapted where an electric motor is used as power and automatic operation is desired.

DISADVANTAGES OF CENTRIFUGAL PUMPS

Must have a comparatively low suction head, preferably not exceeding 15 feet.

Require priming.

Will not efficiently operate if a slight amount of air leaks into the suction line or where there is a large variation in the pumping head.

Lack of flexibility.

PROPER SIZE AND STAGE OF CENTRIFUGAL PUMP TO BE USED

In order to determine this, the following information is required:

Gallons per minute demand.

Total dynamic head.

Nature of fluid to be pumped, whether clear or containing much sediment and grit.

From the above can be determined the characteristics for the particular design of centrifugal pump which will be most efficient.

A certified characteristic curve of the pump at the speed recommended by the manufacturers should be furnished and studied carefully, special attention being given to the following points:

The unloading or non-over load feature in which the power is not increased materially in case the head be reduced.

The efficiency at various heads.

POWER TO BE USED

This pump is adapted to all types of power. If direct-connected to an electric motor it makes an excellent unit and will meet all practical requirements. A flexible coupling should be used in direct-connecting the pump to the motor and both machines should be on the same rigid base to maintain perfect alinement.

As the starting torque is not great, this type of pump may be operated by a squirrel cage motor.

Internal combustion engines direct-connected or with belt-drive are a satisfactory source of power and steam turbine drive can also be used.

METHOD OF INSTALLATION

To obtain efficient operation a special study should be made of each installation. Operating conditions vary to a considerable extent and no set rules may be laid down to fit all cases. Particular care should be taken to be sure the suction and discharge lines cause no strains which may affect the alinement of the pump.

The horizontal, split casing type with enclosed impeller is recommended where conditions are adapted to its use as it presents the most accessible form of construction for inspection and repairs.

A check and gate valve should be placed on the discharge line near the pump.

The pump should be placed as near to the source of supply as possible, especially when operating with a suction lift.

An automatic priming device should be provided or a leather-faced foot or check value installed near the end of the suction line.

HYDRAULIC RAMS (page 896)

Eliminate second sentence in second paragraph, and beginning with the fourth paragraph, the balance of the material. Add the following footnote at bottom of page "For detailed report, see Vol. 28, 1927, page 221; page 896, 1929 Manual."

RELATIVE ECONOMY OF DIFFERENT TYPES OF PLANTS (page 898)

Delete first two paragraphs and first line of third paragraph, including first four words of the second line.

WATER METERS FOR USE IN RAILWAY SERVICE—METHODS OF TESTING, READING AND CHECKING CONSUMPTION (page 952)

Delete "Accuracy of Meters" on page 953 and "Maintenance of Meters" on page 954.

PIPE FOR SERVICE LINES, THREE INCHES AND UNDER IN SIZE (page 901)

Beginning with the second sentence in paragraph 6 on page 902, eliminate balance of paragraph.

STANDARDIZING VALVES AND PACKING FOR WATER SERVICE PUMPS

(page 38, Bulletin 347)

Delete the three paragraphs and substitute the following:

Specifications for packing cover many individual types of dissimilar material and construction, as indicated by the Federal list of specifications. The specifications recommended for consideration in this report cover a limited number of packings most generally used by railroads.

Usually selection can be made from any manufacturer's catalog, but where specifications do not apply, selection may be determined by use of the chart shown below.

SPECIFICATIONS FOR CAST IRON PIPE AND SPECIAL CASTINGS (page 902)

Delete this material, and also the two charts of Standard Dimensions of Pipe, as shown in Bulletin 356, pages 52 and 53.

SPECIFICATIONS FOR HYDRANTS AND VALVES (page 907)

Delete this material.

Inasmuch as the above two specifications were formulated by the American Waterworks Association, and reprinted by permission, it is recommended that they be eliminated, and the following footnote be inserted:

Specifications for Cast Iron Pipe and Special Castings, page 902, 1929 Manual; Bulletin 356, pages 52 and 53.

Specifications for Hydrants and Valves, page 907, 1929 Manual.

SPECIFICATIONS FOR STEEL WATER AND OIL TANKS (page 943)

Make paragraph 8 read as follows:

Minimum thickness of plates:
- Cylindrical part of tank not less than ¼-in.
- For flat bottom not less than 5/16-in.
- For curved bottom thickness should be not less than that of lower plate in cylindrical section.
- Roof—3/16-in.

STEEL SUBSTRUCTURES FOR WATER TANK (page 941)

Add to Article 3—Workmanship:

All connections for steel substructures shall be bolted and the bolts shall be furnished as a part of the steel.

SPECIFICATIONS FOR SODA ASH TO BE USED IN WATER TREATMENT

(page 928)

Delete all this material and substitute the following:

Definition

1. Soda ash is anhydrous normal carbonate of soda.

2. "Light" soda ash is desired under this specification. "Dense" soda ash is not acceptable.

(I) CHEMICAL PROPERTIES AND TESTS

Sampling

3. A sufficient number of bags (not less than 5) will be sampled to be representative of the shipment. A one pound sample will be taken for test.

All samples will be transferred to airtight containers for shipment to the laboratory.

Chemical Properties

4 (a). The properties of soda ash shall be determined by standard methods of chemical analysis.

(b) Soda ash shall conform to the following minimum requirements:
Andydrous Normal Sodium Carbonate 98.0 per cent.

(II) PHYSICAL PROPERTIES AND TESTS

5. The material shall be in dry powdered form and shall be free from ling, chips, ash or other foreign matter.

Insoluble

6. A 100 gram sample shall not have more than 0.5 per cent by weight, insoluble in cold distilled water.

(III) PACKING AND MARKING

Packing

7. Soda ash shall be packed in suitable bags of not more than 100-lb. net weight.

Marking

8. The name of the manufacturer and net weight shall be plainly marked on each package, or attached by tag thereto.

(IV) INSPECTION AND REJECTION

Inspection

9. (a) All soda ash shall be subject to inspection.

(b) The soda ash may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the soda ash ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the soda ash in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection

10. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples by the purchaser.

(b) Rejected soda ash shall be returned to the shipper as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing

11. Samples which represent soda ash shall be preserved in airtight containers for ten working days from the date of test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time.

SPECIFICATIONS FOR HYDRATED LIME TO BE USED IN WATER TREATMENT (page 929)

Eliminate this material and substitute the following:

Definition

1. Hydrated lime is a dry flocculent powder resulting from the hydration of high-calcium or calcium quicklime.

Grade

2. Hydrated lime for water treatment shall be one of the following grades, as specified:

(a) High-calcium hydrated lime
(b) Calcium hydrated lime.

3. The particular class of hydrated lime desired shall be specified in advance by the purchaser. Unless otherwise specified, high calcium lime shall be furnished.

(I) CHEMICAL PROPERTIES AND TESTS

Sampling

4. A sufficient number of bags (not less than 10) will be sampled to be representative of the shipment. A one pound sample will be taken for test.

All samples will be transferred to airtight containers for shipment to the laboratory.

Chemical Properties

5. (a) The chemical properties of hydrated lime shall be determined by standard methods of chemical analysis.

(b) The hydrated lime shall conform to the following requirements as to chemical composition:

(a) High-calcium—90 per cent minimum Calcium Hydroxide $Ca\ (OH)2$
(b) Calcium—85 per cent minimum Calcium Hydroxide $Ca\ (OH)2$

(II) PHYSICAL PROPERTIES AND TESTS

Fineness

6. A 100-gram sample shall leave by weight a residue of not over 2 per cent on a standard 100-mesh sieve and not over 0.5 per cent on a standard 20-mesh sieve.

(III) PACKING AND MARKING

Packing

7. Hydrated lime shall be packed in suitable paper bags of not more than 50-lb. net weight.

(IV) INSPECTION, PENALIZATION AND REJECTION

Inspection

8. (a) All hydrated lime shall be subject to inspection.

(b) The hydrated lime may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of hydrated lime ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the hydrated lime in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(e) All prices shall be based upon the minimum percentage of calcium hydroxide. If a lower grade is furnished than the one specified it may, at the option of the purchaser, be accepted upon making a rebate equal to the percentage of calcium hydroxide below the minimum designated.

Rejection

9. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples by the purchaser.

(b) Rejected hydrated lime shall be return to the shipper as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing

10. Samples which represent hydrated lime shall be preserved in airtight containers for ten working days from the date of test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time."

SPECIFICATIONS FOR QUICKLIME TO BE USED IN WATER TREATMENT

(page 931)

Eliminate this material and substitute the following:

Definition

1. (a) Quicklime desired under this specification for use in water treatment is a burned high-calcium or calcium limestone.

(b) The quicklime desired shall be well burned, free of foreign matter, and unburned or overburned rock, and shall be capable of disintegrating in water into a suspension of finely divided calcium hydrate.

Grade

2. Either of the following grades will be furnished as specified:
    (a) High-calcium quicklime
    (b) Calcium quicklime

Forms

3. This material will be shipped in the form specified:
    (a) Lump—Kiln size (selected).
    (b) Pebble—Kiln size (selected).
    (c) Ground—Reduced in size to pass a ¼-in. screen.
    (d) Pulverized—Reduced to fineness designated.

CHEMICAL PROPERTIES AND TESTS

(I) SAMPLING

4. A sufficient number of barrels (not less than 5) shall be taken from various parts of the shipment, dumped, mixed, and sampled. The sample shall comprise at least 10 shovelfuls taken from different parts of the pile. The total sample taken shall weigh at least 100-lb. and shall be crushed and quartered to provide a one pound sample for the laboratory.

Laboratory Samples

5. Material shall be placed immediately in airtight containers for shipment to the laboratory.

(II) CHEMICAL TESTS

Chemical Properties

6. (a) The chemical properties of the quicklime shall be determined by standard methods of chemical analysis.

(b) Chemical composition shall conform to the following requirements:

(a) High-Calcium quicklime—Available Calcium Oxide..90 per cent minimum
(b) Calcium quicklime—Available Calcium Oxide.......85 per cent minimum

(III) PACKING

Packing

7. Quicklime shall be shipped in wooden or steel barrels, or other suitable containers.

(IV) INSPECTION AND REJECTION

Inspection

8. (a) All quicklime shall be subject to inspection.

(b) The quicklime may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturers plant which concern the manufacture of the quicklime ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be conducted so as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance of rejection of the quicklime in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection

9. (a) Unless otherwise specified, any rejection based on the failure to pass tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples by the purchaser.

(b) Rejected quicklime shall be returned to the shipper as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing

10. Samples which represent quicklime shall be preserved in airtight containers for ten working days from the date of test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time.

SPECIFICATIONS FOR SULPHATE OF ALUMINA TO BE USED IN WATER TREATMENT (page 933)

Eliminate this material and substitute the following:

Definition

1. This chemical shall be known as the commercial product known as Basic Sulphate of Alumina.

(I) CHEMICAL PROPERTIES

Sampling

2. A sufficient number of bags will be sampled to be representative of the shipment. A one pound sample will be taken for test.

All samples will be transferred to airtight containers for shipment to the laboratory.

Chemical Properties

3. (a) The chemical properties of the basic sulphate of alumina shall be determined by standard methods of chemical analysis.

(b) The sulphate of alumina shall be basic and conform to the following requirements:

Water soluble aluminum sulfate equivalent to 17 per cent Al_2O_3 minimum.

(II) PHYSICAL PROPERTIES AND TESTS

4. The material shall be in dry granulated or lump as specified and shall be free from lint, chips, ash or other foreign matter.

(III) PACKING AND MARKING

5. Basic sulphate of alumina shall be packed in suitable bags of not more than 100-lb. net weight, or in barrels or containers of not more than 300-lb. net weight.

6. The name of the manufacturer, net weight and sulphate of alumina shall be plainly stenciled on each end of package or marked on tags securely attached thereto.

(IV) INSPECTION AND REJECTION

Inspection

7. (a) All sulphate of alumina shall be subject to inspection.

(b) The sulphate of alumina may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while working the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the sulphate of alumina ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the sulphate of alumina in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection

8. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples by the purchaser.

(b) Rejected sulphate of alumina shall be returned to the shipper as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing

9. Samples which represent sulphate of alumina shall be preserved in airtight containers for ten working days from the date of test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time.

SPECIFICATIONS FOR SULPHATE OF IRON TO BE USED IN WATER TREATMENT (page 935)

Eliminate and substitute the following material:

Definition

1. Sulphate of iron is the ferrous sulphate, the formula of which is $FeSO_4 7H_2O$.

Class

2. Unless otherwise specified, granular sugar sulphate of iron will be furnished.

(I) CHEMICAL PROPERTIES AND TESTS

Sampling

3. A sufficient number of bags will be sampled to be representative of the shipment. A one pound sample will be taken for test.

All samples will be transferred to airtight containers for shipment to the laboratory.

Chemical Properties

4. The chemical properties of the material shall be determined by standard methods of analysis, and the shipments shall conform to the following minimum requirements:

(a)	Ferrous sulphate anhydrous	53.5 per cent minimum
(b)	Free sulphuric acid	.025 per cent maximum
(c)	Insoluble impurities	2 per cent maximum

(II) PACKING AND MARKING

Packing

5. Sulphate of iron shall be packed in suitable bags of not more than 100-lb. net weight, or in barrels or containers of not more than 250-lb. net weight as specified in purchase order.

Marking

6. The name of the manufacturer, name of material and grade of sulphate of iron shall be stenciled on each package, or marked on tag securely attached thereto.

(III) INSPECTION AND REJECTION

Inspection

7. (a) All sulphate of iron shall be subject to inspection.

(b) The sulphate of iron may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the sulphate of iron ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the sulphate of iron in his laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection

8. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples by the purchaser.

(b) Rejected sulphate of iron shall be returned to the shipper as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing

9. Samples which represent sulphate of iron shall be preserved in airtight containers for ten working days from the date of test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time.

MINIMUM QUANTITY OF SCALING AND CORROSIVE MATTER WHICH WILL JUSTIFY TREATMENT (page 920)

Change heading to read "Minimum Quantity of Scaling and Corrosive Matter Which Will Justify Complete External Treatment."

Delete material in Manual and substitute the following:

The minimum quantity of solids in solution that will justify treatment depends on local conditions and the composition of the solids. By applying the proper local values to the equation given below, this quantity can be determined.

X = Number of pounds of dissolved solids removed from water or rendered non-incrusting per year.

B = Money value of benefits received from treating one pound of dissolved solids; this will include;

Saving in boiler washing and repairs.
Saving in fuel.
Saving in reduction of locomotive failures.
Increased service obtained from locomotives.

C = Cost per pound of dissolved solids treated, to provide treating facilities, as follows:

Cost of labor.
Cost of fuel or power.
Cost of chemicals.

Cost of current repairs.
Cost of additional blowing off to prevent foaming.
Cost of testing and supervising water treatment.
Cost of additional taxes and insurance.

D = Cost of treating plant installed.
I = Interest per annum on D.
L = Estimated life of treating plant in years.
R = Estimated value of materials recovered from plant after L years.
S = Annual depreciation of plant, equivalent to a sum per year, which, if placed in a sinking fund at I rate of interest, would amount to D–R in L years.

The following equation gives the point where the benefits from treating the water will balance the cost of treating:

$$XB = XC + S + I \quad \text{.......}(1)$$

$$X = \frac{I + S}{B - C} \quad \text{.......}(2)$$

If more than this amount of dissolved solids is removed, or rendered non-incrusting, the treating plant will be economical.

In order to gain full benefits from water treatment *all* possible scale forming solids in the water evaporated by locomotives should be treated. Wherever conditions, as enumerated above, do not justify the installation of complete softening plants some means of introducing suitable chemicals to neutralize the non-carbonate hardness of the water should be provided. While increased blow-down over that necessary with lime-soda softening will be required to prevent foaming, this method is relatively inexpensive and is justified wherever non-carbonate hardness is present and the water is regularly used.

(Note.—Values for *"B"*, as determined by various investigators, vary from 13 to 17 cents per pound of dissolved solids removed. Thirteen cents per pound of scale forming dissolved solids removed or rendered non-incrusting has been accepted as a conservative standard by the Committee on Water Service of the AREA. See Vol. 15, 1914, page 691; Vol. 26, 1925, page 380; Vol. 27, 1926, page 197.)

FOAMING AND PRIMING (page 919–920)

Delete and substitute the following material:

"Foaming" is the term applied to the action in a boiler when steam bubbles build up over the surface of the water to form a layer of foam which fills the steam space and carries over into the cylinders.

This action is due to the amount and type of impurities present in the water. The impurities which concentrate and cause foaming are dissolved solids and suspended matter, either of which may be of organic or inorganic origin. These impurities seem to increase the strength or tenacity of the thin films surrounding the steam bubbles, and as the bubbles rise to the surface, they retain their films and collect to produce foam.

The concentration of foaming salts reaches a critical point, depending upon the type and work of the locomotive boiler, the amount and character of the alkali salts, and the amount and type of suspended matter in the water. To prevent foaming the concentration must be kept below this point. The best results are obtained by the systematic and frequent blowing off of boilers. The cost of maintaining the concentration below the critical point equals the cost of pumping, treating and heating to boiler temperature the amount of water blown out.

When the concentration of foaming salts is so great that the required amount of blowing off is impractical or uneconomical, anti-foaming compounds may be used with good results.

"Priming" is the term applied to the instantaneous evolution of steam from a heating surface, which suddenly carries water in large volumes into the steam space. This action is mechanical and may be due to poor design of the boiler, a sudden opening of the throttle, or working the boiler beyond its capacity. It is independent of the character of the water. While the effect upon the locomotive is temporarily the same, priming differs from foaming in that it can be mechanically controlled to a large extent by proper operation.

(Carrying water unnecessarily high in the boiler is conclusive of both foaming and priming.)

WATER SERVICE RECORDS (page 954)

This Committee accepts forms adopted by the Committee on Records and Accounts, covering water service records and substitutes the following for forms now appearing on pages 955, 956, 957:

Form 1130—Cost of Water Production
Form 1131—Monthly Report of Water Station Operation
Form 1132—Quarter Monthly Report of Water Treating Plant Operation
Form 1133—Record of Water Station Facilities

Form 1304, page 958 of the Water Service Committee, is renumbered Form 1134.

SEWAGE DISPOSAL WHERE SANITARY FACILITIES ARE NOT AVAILABLE

The germs of typhoid fever, dysentery, and other intestinal diseases occur in nature only in the discharges from the human body or in substances contaminated with these discharges. Human beings contract such diseases only through swallowing such contaminated matter with food or drink. The parasitic disease of hookworm which occurs in widespread areas in portions of the United States, is also amenable to control by proper disposal of human waste. Hence the controlled disposal of human waste is a very important public health matter and the following description of methods for human waste disposal are for the guidance of railway officers where sewage connections are not readily available. No set of standards are presented owing to the difficulty of harmonizing the many Federal, state, and municipal regulations in the field of sanitation with the practical railroad application.

Choice of Methods

A—Large groups of employees and patrons.
  Terminals with dwellings, offices and shops.
  Permanent camps.
  Large mobile labor camps.

B—Small groups of employees or patrons.
  Freight and passenger stations.
  Section houses, etc.
  Small mobile labor camps, such as B&B and water service.

For permanent installations with many individuals to be served, there is the choice of:

Water carriage (plumbing and sewerage) and disposal by dilution or adequate treatment.
Septic tank or cesspool with or without disposal by dilution or treatment.
Chemical or septic toilets.
Privies.

For mobile units there is the choice of:

Chemical toilets.
Portable privies.
Portable seat boxes with collapsible shelter walls.

Modern sanitation will demand water carriage wherever feasible and within the limits of reasonable cost, but in all such cases competent sanitary engineering advice should be obtained to plan such installations in accordance with state and municipal regulations.

Septic Tank

The septic tank does not purify sewage. Its purpose is to separate and hold solid particles in the tank in order that the liquid may be discharged clear or nearly so. This liquid or effluent will carry bacteria and will itself decompose and produce odors. It may therefore be necessary to dispose of it by dilution in a stream or through subsurface tile drains in sandy soil, where the decomposition can continue without creating a nuisance. In no case should such an installation be made in a manner to contaminate a source of drinking water.

Chemical Toilets

The chemical toilet consists of a metal tank charged with a caustic solution which liquifies the fecal matter, kills bacteria and produces little or no odor. Generally the size of the tank is such that it will provide service for six months or longer. The contents of the tank can be discharged through drain connections into cesspools.

Septic Toilet

The septic toilet consists of a bowl directly connected by a short tube to a septic tank, the whole being operated as a dry system. Unlike the septic tank which receives an abundance of water automatically by the flushing of toilets, the septic toilet receives only such amounts as the users see fit to order to maintain a constant water level in the tank. This type of installation is not particularly suitable for railway service involving a large number of users.

Pit Privies

The essential requirements are a pit and a fly-tight seat, close fitting lids, and sealed joints between the housing and pit. The pit should be of sufficient size to accommodate the number of seat holes. The construction of pit privies has become so standardized by Federal and state regulation that the railway officer should consult the U. S. Public Health Service or his State Board of Health for plans and specifications before attempting installations. Care should be taken to locate a pit privy so there will be no danger of contaminating a private or public water supply.

Mobile Units

The sanitary requirements for portable seat boxes with collapsible shelter walls are similar to those given for privy houses. They are constructed so they may be transported and set up over pits. Chemical toilets may be set up in a camp car, with tanks hung below the floor, and good sanitation be maintained.

(For additional information, see Vol. 34, 1933, pp. 92–100).

DISINFECTANTS, DEODORANTS, FUMIGANTS AND CLEANING MATERIALS

Disinfectants

Disinfectants are used to destroy germs and insects, but since a disinfectant is not necessarily an insecticide it is imperative that the user choose the proper product for the work at hand.

In general, the mass of trade-named disinfectants can be divided into four classes: coal-tar and pine-oil products, chlorine and formaldehyde solutions. The phenol coefficients of these products vary from 0.5 to 20. The application of disinfection would be in the cleaning or handling of:

Toilet bowls or urinals
Cuspidors
Floors and walls
Boats, stock cars and stock yards

No single disinfectant is appropriate in all cases. Select the proper substance and allow ample time for it to work. Success depends largely upon the care and exactness of the person who prepares and applies the disinfectant.

For the first three items listed above, some type of coal-tar or pine-oil disinfectant with sufficiently high phenol-coefficient is suggested. This is mixed with water in amounts as indicated by the strength of the solution. It may be applied with mop, cloth or other means in the same manner as a soap solution. Federal and state regulations for the use of disinfectants used for cleaning prescribe minimum requirements. For the disinfection of stock cars, boats, stock yards, etc., solutions as noted in Bureau Animal Industry Order 309 are required.

Deodorants

Deodorants are substances which have the power to destroy or neutralize unpleasant odors but are usually without power either as disinfectants or fumigants. There are many volatile oil products on the market which are sold as deodorants but which are merely substances of pungent odor which simply cover up one smell with another. A better appreciation of sanitation in recent years has led to more thorough cleaning of buildings and equipment rather than the disguising of poor cleaning.

Fumigants

Insecticidal fumigation is a process of confining a toxic vapor in an enclosed space, destroying insect life in all stages, including eggs, larvae, pupae, and adults. Fumigation properly done, not only completely eliminates infestation in one short operation, but is a clean process, leaving no odors or bad after-effects. It is used as a means of conserving materials against insect damage, for checking the transmission of disease by insects and rodents, and for the improvement of general sanitary conditions. This method is also used to destroy germs, though a different type of fumigant is necessary.

The most common insecticide fumigant is hydrocanic acid gas. HCN is not a germicide. It should be used in the hotel or household only with the greatest care as the least carelessness with it may mean the loss of human life. Hydrocyanic acid and other gaseous cyanogen compounds, including cyanogen chloride are distinct from all other fumigants in general use, in the rapidity in which poisoning is induced. In the hands of the ignorant or careless, fumigation is a menace to all concerned. A gas mask should be used in all fumigating operations. If there is any cause to suspect the reliability of the canister of the mask, it is best to secure a new one. A type approved by the U.S. Bureau of Mines is recommended.

Due to the special hazards resulting from fumigation with deadly gases, many municipalities have passed ordinances requiring permits which specify certain precautions to be followed. An important item in these ordinances is that of posting danger signs, prior to fumigation, on all doors or entrances to the premises. Bulletin 513 of the Department of Agriculture also gives considerable data on HCN and lists many important precautions. To become negligent in *Any* of these may cause serious results, perhaps loss of life.

HCN for fumigation is available in liquid form in heavy steel cylinders, being forced through a hose and out a spray nozzle by air pressure; as liquid HCN absorbed in Fuller's Earth, in heavy cans; as liquid HCN absorbed in unsized wood pulp or paper discs, packed in cans; or as Calcium cyanide, a fine powder, in heavy cans.

Cleaners

Ordinary soaps have but limited disinfecting power. This is not marked enough to make them trustworthy disinfectants, despite their great value as detergents. Many of the pine-oil and coal-tar disinfectants are also suitable for cleaners and as such are widely used on railroads. Many of these are harmful to various types of floors and care should be used to select the proper product. The effective cleaning compound should be capable of easily saponifying animal fats, oils and greases, also readily emulsifying mineral oils and greases. The effective cleaner must do its work quickly and economically in hot or cold weather. The success and economy of any cleanser for any usage depends greatly on its proper application. Select the proper cleanser for the particular problem, apply as instructed and proper results will be obtained.

The disinfecting, fumigating, and cleaning problems on railways are legion. For each type of problem there are available compounds or solutions designed for each purpose. The problem of the railway officer assigned to sanitation work is to select the proper substance for the particular type of work he has at hand,—one which will do the work efficiently, quickly and economically.

Appendix B

(4) CAUSE OF AND REMEDY FOR PITTING AND CORROSION OF LOCOMOTIVE BOILER TUBES AND SHEETS, WITH SPECIAL REFERENCE TO STATUS OF EMBRITTLEMENT INVESTIGATIONS

R. E. Coughlan, Chairman, Sub-Committee; J. H. Davidson, O. E. Mace, M. E. McDonnell, O. T. Rees, R. M. Stimmel, C. P. Van Gundy, J. B. Wesley.

During the past year, this Committee has endeavored to compile available information regarding the particular type of boiler trouble generally appearing as the cracking of boiler plates and rivets along the riveted seams below the water line of the boiler. This trouble is generally called "Caustic Embrittlement" or simply "Embrittlement."

This boiler cracking first came to the attention of operators in boiler plants during the year 1912 at the University of Illinois. From that time on, it has appeared in various sections of the country and has extended to locomotive boilers as well as stationary boiler plants operating under certain conditions and with types of water generally known as alkaline, i.e., waters containing free sodium carbonate.

Detailed investigations, conducted by various technical societies and research engineers, have developed the information that this type of boiler trouble results from a variety of causes, such as construction, operation of boilers, and character of feed water.

Practically all authorities now agree that this type of cracking is usually characterized by the following:

(1) The failures occur only in parts of the boiler reached by water.

(2) They are found only in those regions of the submerged metal particularly subject to high localized stresses, i.e. riveted seams and rolled tube ends.

(3) Those regions are also the only ones in which the boiler water might conceivably become concentrated above its normal value.

(4) The cracking does not commence on the surface of the metal in free contact, with the boiler water, but rather where two separate pieces of steel, as a plate and a butt strap, a rivet and a plate, or a tube and a plate are adjacent to each other.

(5) The obvious cracks are extremely irregular; although they generally follow the line of rivets, they frequently run past each other; occasionally they start in the solid plate between rivets but more frequently at rivet holes; the microscopically visible cracks are predominantly intercrystalline.

(6) There is no elongation of the steel or deformation of individual grains such as is observed when normally ductile metal fails.

(7) The failures occur in steel with excellent chemical and physical characteristics as well as in materail of poorer grade.

Numerous remedies have been suggested for the elimination of this trouble, the most commonly used being—

(1) The use of sulphate of soda in accordance with the boiler code of the American Society of Mechanical Engineers.

(2) The use of phosphates as a substitute for sodium carbonate.

(3) The use of organic material, principally tannin.

Inasmuch as the investigations, up to the present time, have disclosed no definite cause as to the actual reason of this trouble, it is the recommendation of the Committee that this subject be reassigned for further study and this report be received as information.

Appendix C

(6) TYPES OF LIME AND SODA ASH EQUIPMENT IN TREATED WATER

H. E. Silcox, Chairman, Sub-Committee; J. H. Davidson, B. W. DeGeer, J. P. Hanley, A. W. Johnson, C. P. Richardson, H. L. Roscoe, R. E. Wachter.

The oldest method of water softening for locomotives, and large boiler installations is by treatment with lime and soda ash before the water goes to the boiler.

In its earliest and simplest form as used by Dr. Clark of Aberdeen, Scotland, in 1840, the equipment consisted of two tanks which were alternately filled with raw or hard water, dosed with the proper amount of fresh lime, well agitated and allowed to settle to remove the bicarbonates.

Later the treatment was improved by William Porter in England to include the use of soda ash to eliminate the non-carbonate hardness, and in course of time this method of softening and cleaning water, known as the Clark–Porter process, became known as the lime-soda treatment.

About 1880, with the aim of cheapening the installation and speeding up the process, one small tank was used for continuous mixing of chemicals with a stream of raw water, and one large tank for settling the precipitate from the continuous stream. From this date the first method (with one or more large tanks) has been known as the "intermittent process" and the other as the "continuous process." Both are satisfactory and give good results in water treatment. The term "continuous" implies the addition of the softening chemicals to the water as it is pumped so that it flows, in turn, through reaction and sedimentation chambers, the softened and clarified water being delivered from the latter to a storage tank or direct to service lines.

While both of these methods continue to be known as the "Lime-Soda Process" because of the common use of these reagents, the equipment is complete for the use of any reagents or any variation of method which the character of the water may demand. If the water carries coloidal matter, or for any other reason is difficult to settle or chemical reaction is slow, a coagulant can be added as part of the process in combination with lime and soda ash or by separate feed.

According to records available, the first continuous plant for softening water on an American railroad was installed in 1900 on the Denver & Rio Grande Western Railway at Helper, Utah.

At the present time plants of this type in railroad service vary in capacities from 12,000 to 150,000 gallons per hour, with settling tanks of diameters ranging from 12 feet to 62 feet and heights to meet service requirements.

In the earlier types of continuous plants the chemicals were pumped from a vat at a constant rate by means of a small steam pump, being discharged at the top of the treating tank into a chamber where they were mixed with the raw water, allowed to react and treated water drawn off by means of troughs or floating outlet pipes. This type of equipment did not permit the variation in chemical control required to maintain a constant ratio between the chemicals and raw water delivery, and often resulted in an over or undertreatment.

The next step in chemical control was known as the top operated plant in which all of the chemical equipment was installed on top of the treating or settling tank. This apparatus consisted of a round or square chemical mixing vat with agitator, which was driven from a water wheel operated by the raw water delivery or an electric motor. Chemicals were delivered to the raw water by gravity through a floating outlet pipe in the chemical vat which was lowered by means of a cable connection to float and counterweight in a proportioning tank which was filled with water delivered through weir or orifice arrangement of many designs located in a box into which the raw water was discharged prior to entering the downtake tube. This type of plant necessitated the elevating of chemicals to top of softener, which was objectionable account inconvenience in keeping a check on the operation and in making repairs. Most later developments have been centered on ground-operated chemical vats and proportioners.

With the later development, the weir and orifice were retained on top of tank and the flow piped to ground proportioner tank, the chemical mixture flowing from the chemical vat into a sump from which it is pumped to the top of settling tank and mixed with the raw water.

Another type plant was developed for ground operation in which the chemicals were mixed in a square or rectangular vat, pumped continuously into a container located at top of softener above the downtake tube, the raw water being discharged into a tipping bucket which operated a valve in the bottom of chemical container allowing a gravity flow of chemicals for each dumping of raw water. The ratio was then regulated by varying the concentration of chemical solution or the chemical container valve setting.

In the development of modern treating plants, the chemical equipment embraced such devices as simple displacement water motors (or engines) of various sizes connected to chemical pumps, orifices, weirs, tipping meters, venturi tube, and meter controls for constant and variable feeds. Such controls have been found to provide sufficiently accurate proportioning for dependable results if given the required attention and supervision.

Different types of proportioning equipment are described in the following:

Water Motor Type

This device is a reciprocating type of motor (or engine) which is operated by raw water being discharged through it and in turn driving a pump delivering a proportionate amount of chemical solution. This type of equipment will maintain a chemical ratio with fluctuating water deliverey and is particularly adaptable to locations where electric power is not available. The economical operating range of this equipment is 100 to 600 g.p.m. Illustrations of this equipment are shown on pages 276 and 277 of Volume 33, 1932.

Weir, Orifice and Tipping Meter Type

This method provides a control by which a proportionate amount of the raw water delivery is by-passed to a chemical float chamber or tipping meter, which in turn lowers outlet pipe in vat allowing flow of chemical solution to suction of pump in direct ratio to raw water pumping rate. This type is adaptable to plants of any capacity. Fig. 1 and 2 illustrate application.

Venturi Tube Types

With this type of control the raw water passes through a venturi tube located in the discharge line, differential pressure operating a control valve which in turn regulates water delivery to a uniform rate. In such installations the chemical solution is pumped at a constant rate depending on tube to control pump delivery of raw water. The venturi tube is also adapted for use with a variable rate chemical feed, in which application the control valve is eliminated and differential pressure is utilized to regulate flow of chemical solution to pump suction. Application of this type control is used in large capacity plants and with installations in which the raw water delivery is fairly uniform.

Meter Controls

In the application of this method, a meter is installed in the raw water discharge line fitted with a drum for cable control to swinging pipe in chemical vat or electrical attachment which controls the lowering of chemical outlet pipe by means of electro magnet ratchet appliance. With installations of this type the chemical solution is delivered to pump suction at a uniform ratio to the raw water passing through meter. Controls of this type are adaptable to all capacity plants and in particular to those with a fluctuating raw water deliverey, as is often the case with city or river supplies in which the pumps work under varying heads. Typical application of this type of installation is shown in Fig. 3.

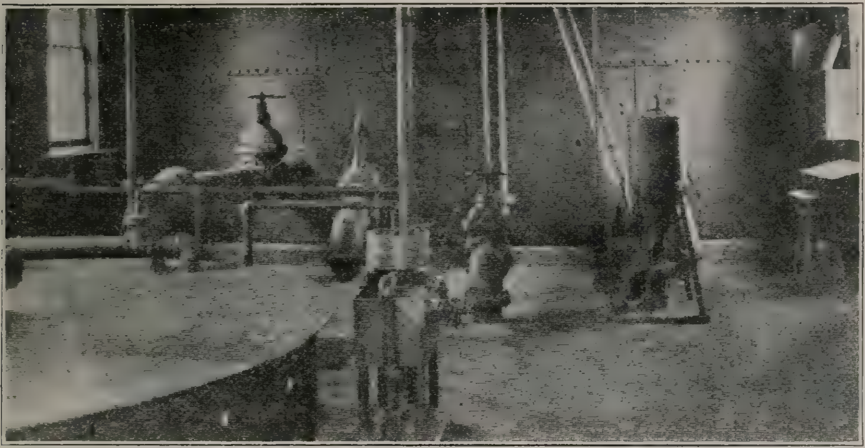

FIG. 1.—Tipping Meter and Dry Feed.

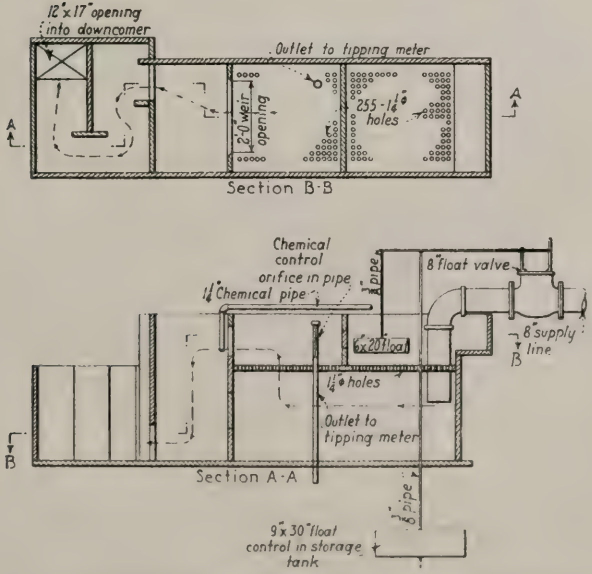

FIG. 2.—Horizontal and Vertical Sections of the Wier Box.

A

Chemical Mixing Vats

The chemical mixing vats in use in modern treating plants are of two distinct designs (a) vertical agitation installed in either round or square vats, (b) horizontal agitation in square or rectangular vats with cylindrical bottom. Either type is adaptable to dependable service and selection should be based on space available and capacity required for proper treatment of water supply. The agitating apparatus may be driven by water or electric motor. Satisfactory speeds of vertical agitators range from 8 to 12 r.p.m (peripheral speed 120 to 190-ft. per minute) and horizontal 5 to 8 r.p.m. (peripheral speed 115-ft. per minute.)

In selection of chemical vat, consideration should be given to the requirements for treating the respective raw water supplies, using one of sufficient capacity to run plant for 12 to 24 hours with a chemical solution not exceeding 0.5-lb. of lime per gallon of water in vat. Chemical solutions of greater density may be used in special cases but more agitation power is required together with liability of sticking agitator blades in starting plant.

Chemical Pumps

There are many type pumps manufactured which are adapted for pumping chemical solutions. Those most universally used are: simplex, duplex and triplex single acting plunger power driven, and centrifugal motor driven pumps with open type impellers. The size and capacity of such equipment depend on requirements of plant. The power pumps are usually driven by chain drive from an extended shaft on the chemical vat.

Control of Power

It is essential that the chemical equipment be started at the same time raw water supply enters the reaction chamber, and is stopped when supply is cut off in order to maintain uniform treatment. This is accomplished with automatic electric control operated by increased pressure in discharge line or direct connection to controls of the raw water pumps. There are many dependable types of equipmnt manufactured which are adaptable to this service.

Coagulent Equipment

In the treatment and clarification of certain raw waters containing coloidal matter, it is not possible to produce clear softened water by mixing the coagulant with the lime and soda ash. In order to secure complete clarification auxiliary equipment may be installed, comprising a small coagulant vat from which a solution of alum, copperas, sodium aluminate, or other reagent can be pumped at a constant rate. A small electric motor driven pump may be used for this purpose discharging coagulant directly into the raw water line as illustrated by Fig. 8-A on page 280 of Volume 33, 1932. Other types of coagulant feeding apparatus are available for handling dry reagents which are used successfully in numerous installations; one type is shown in Fig. 1.

Repumping Sludge

In many plants where the high hardness and character of water justifies, sludge recirculating pumps are used to draw the sludge from the bottom of the sedimentation tank, discharging it directly into the raw water line or into mixing chamber at top of downtake tube. The object of this recirculation is to provide small particles of solid matter that aid in the formation of floc of precipitated matter and thus facilitate clarification. In addition it affords opportunity for further utilization of unexhausted chemicals that may be discharged in the sludge. Fig. 4 illustrates recent development along

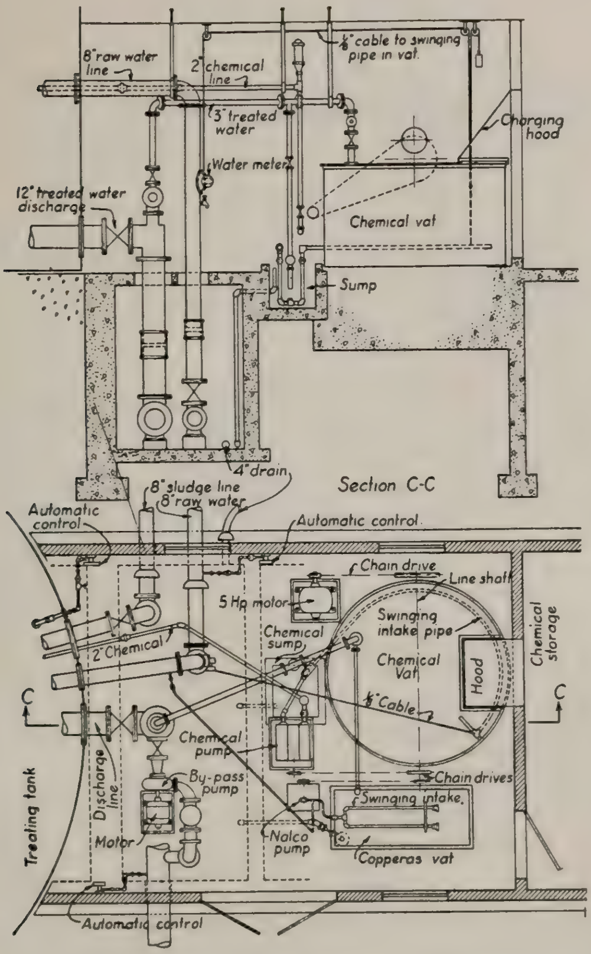

FIG. 3.—Floor Plan and Section of the Chemical Control Room.

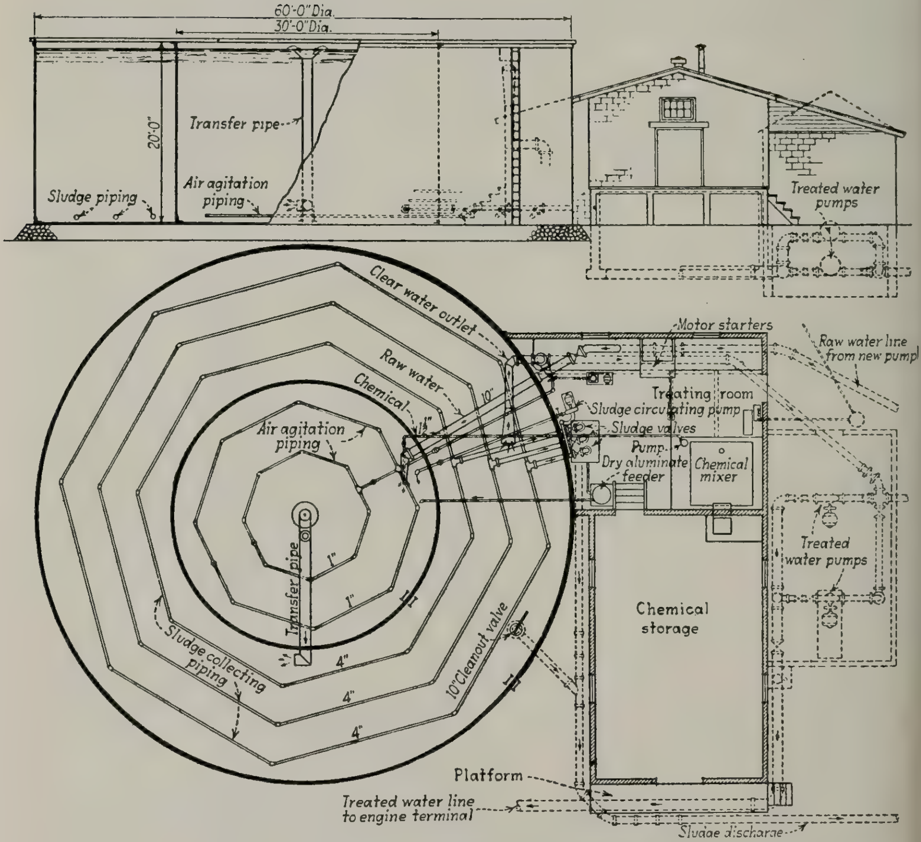

FIG. 4.—Air Agitation with Sludge Repumping.

this line on the Chicago & Northwestern Railway. Centrifugal pumps with open type impellers are adaptable for this service.

Conclusions

(1) The mechanical device for introducing reagents must be such as to insure as near as possible a quantity of reagent in direct proportion to the flow of untreated water.

(2) The type of equipment for such installations can best be determined by a careful study of all local conditions giving consideration to annual operation and maintenance charges.

Appendix D

(9) WATER CONDITIONS AFFECTING THE EXTENSION OF LOCOMOTIVE WASHOUT PERIODS

J. B. Wesley, Chairman, Sub-Committee; R. W. Chorley, R. E. Coughlan, B. W. DeGeer, R. N. Foster, O. E. Mace, R. H. Miller, E. R. Morris, Owen Rice, R. M. Stimmel.

Operation of steam locomotives over extended washout periods has been demonstrated to be practical and economical under general water conditions found throughout the country. Some roads have operated on this basis for a number of years, while other roads have only recently adopted the custom of washing locomotive boilers only at monthly inspection time. Of 19 roads giving information on this subject, 8 are operating the full 30-day period permitted by law between washouts; 5 are operating part of their locomotives on this basis; and 6 are making no efforts along this line. No road has been reported which, having once established its locomotive operation on the extended washout basis, has returned to frequent boiler washing practice.

A number of factors have united during the past few years to bring this subject to the attention of railroad managements, and considerable interest in the subject is manifest on many roads that still operate with the frequent washout and water change practice. With greater investment in larger and more powerful locomotives it becomes desirable to keep the engine in active service as much as possible; the extension of locomotive runs makes it necessary that the water in the boiler be conditioned without taking the locomotive out of service for boiler washing; and decreased revenues during the depression have centered attention on possible sources of economy, both in operation and maintenance.

Boiler Conditions Produced by Water

Water, as found in nature, is never pure. It carries various mineral, organic and gaseous substances in solution, with frequently mineral matter in suspension—mud. These impurities in water are present in varying quantities, depending mostly on the nature of the soil over which or through which the water has traveled. Five major adverse boiler conditions are produced by water conditions, namely:

(1) Scale formation on the heating surfaces
(2) Corrosion of boiler metal
(3) Leaking conditions
(4) Mud or sludge accumulation
(5) Foaming

Some of these conditions can be corrected by boiler washing while others cannot be so corrected.

(1) SCALE FORMATION is caused principally by the deposition of calcium and magnesium compounds when water containing them is heated or evaporated in boilers. Boiler washing does not prevent or correct this condition, as the scale when once formed in place adheres too tightly to be dislodged by a stream of water. The removal of scale from heating surfaces is effected by mechanical means, such as bombarding the sheets and stays, by scraping and sandblasting, and by rattling the flues—not by washing.

(2) CORROSION OF BOILER METAL is a more complicated phenomenon. Briefly, it is caused by any one of a number of water conditions, metal characteristics, stresses in the boiler assembly, or by a combination of two or more of these conditions. The definite cause in any particular instance is frequently difficult to determine. But boiler washing is not known to be, nor is it advocated to be a corrosion preventive.

(3) LEAKING OF BOILERS, so far as pertains to water conditions, is mainly caused by scale deposits and by corroded metal; so its prevention or correction depends on the elimination of its two causes. Boiler washing does not prevent the development of this condition but frequently aids it. Correct application of chemicals to the natural water will reduce scale formation to a satisfactory minimum, and this chemical treatment usually carries the best antidote for that corrosion which is caused by water conditions. So proper chemical treatment of water to prevent scale formation also prevents most corrosion of boiler metal. With these two conditions eliminated the development of leaking conditions also stops. Boiler washing does not and cannot prevent the existence of the above three conditions.

(4) MUD, OR SLUDGE, as found in boilers, has two sources. It comes from suspended matter in water—that is, from muddy water—and also from the temporary hardness in solution which precipitates out as sludge when the water is heated in the boiler. A water with high temporary hardness, though perfectly clear, can put as much mud in a boiler as does a "muddy water." The first type of mud—that of muddy water—can be romoved from the water either by filtration or by sedimentation. Usually where sedimentation is used the water is also chemically treated for removal of scale-forming matter, thus getting rid of both the suspended mud and the temporary hardness mud. If the mud materials are permitted to enter the boiler they can be drafted out through the blow-off valve or they can be washed out.

(5) FOAMING is the term applied to the condition in the boiler when steam bubbles develop to such an extent that the bubble films and entrained water are carried to the cylinders with the steam. Disregarding the mechanical and operating features that affect the occurence of this condition, it is sufficient to say that foaming is caused by the presence of suspended matter (mud) or alkali salts (foaming salts) in the water, or a combination of the two. In actual operation the combination usually exists. *There is no economic chemical treatment that will remove the foaming salts,* and since these salts remain in solution in the water in the boiler, the prevention of foaming depends on removing all the foul water from the water—that is by washing the boiler or changing the water—or on blowing out at proper intervals a part of the foul water and refilling with fresh water.

These considerations show us that the five adverse conditions produced in boilers by impurities in water, only two of them—mud accumulation and foaming—can be corrected by boiler washing. Yet these two conditions can be corrected by other means too. If the other methods of correction will permit more continuous operation of the locomotive, making possible longer locomotive runs, and if they produce greater economy in operation and maintenance of the machine, then they merit consideration.

Conditioning Water in Boilers by Systematic Blowing

When water with its impurities is taken into a boiler and evaporated the pure water passes out in the form of steam while the impurities remain inside the boiler. As water continues to be evaporated the impurities accumulate in the water left in the boiler, and when a sufficient degree of concentration has been produced, foaming takes place. The degree of concentration required to produce foaming varies considerably with the different ratios of mud to alkali salts in the waters used, also with the varieties of alkali salts predominant in the waters. But for any one operating district this is a fairly constant condition. The critical foulness to cause foaming usually lies between 100 and 200 grains per U.S. gallon of foaming or alkali salts. The concentration of these salts in the boiler must be maintained below this critical condition if foaming is to be prevented and satisfactory operation secured.

Evaporation of water in a boiler is comparable to burning coal in the firebox. When coal is burned the "pure" part goes out of the stack in the form of gases, the impurities in the coal remain in the firebox as ash. If these impurities are permitted to remain and accumulate in the firebox it will be only a relatively short time until the fire is smothered and the engine fails for steam. In operation the fireman shakes the grates, no accumulation of the impurities is permitted, a good fire condition is maintained, and no failure occurs. Likewise with the water. If part of the accumulated impurities in the boiler are blown out through the blowoff at sufficiently frequent intervals, the concentration of foaming salts that cause foaming is not reached, and no foaming occurs. Keeping the boiler clean by opening the blowoff valve is just as effective as keeping the fire clean by shaking the grates, and there is no more excuse for an engine failure or train delay from the occurrence of foaming than there is from a dirty fire condition.

Most railroads do not have all water supplies chemically treated to prevent scale formation, corrosion, and leaking conditions; some water supplies at times have mud in them, and many supplies contain considerable quantitites of alkali salts to help cause foaming. In considering the operation of locomotive boilers over extended washout periods, up to the 30-day limit, a number of questions arise. What are the fuel losses attendant on the blowing required to prevent foaming? Can hard waters be used, and if so, to what degree of hardness? How do muddy waters affect this type of operation? What limits of alkali, or foaming, salts can be handled satisfactorily by this method? What equipment is required for operating the blowoff? What supervision is necessary? What objections are there to blowing boilers on line of road? And what benefits are secured? To properly answer these questions it is necessary to get information from the experience of those roads that have used this system of operation for a number of years.

Fuel Losses from Blowing

In the matter of fuel consumption, there is a certain loss of heat units attendant on blowing hot water from the boiler. But this loss is more than offset by the reduction in the terminal handling cost, due to fewer washouts and water changes being made. This is clearly shown in the two 30-day operating test reports comparing the cost of boiler conditioning by blowing with the cost of conditioning by washing the boiler and changing water.

CASE I

Thirty-day operating period—one washout—no water change—52 trips of 170 miles—8840 miles operated

Item	*Per Single Trip*		*170 miles*
Terminal blowing (@ 48¾¢ per M Gal.	82 seconds	451 gallons	$0.23
Road blowing (@ 48¾¢ per M Gal.	292 “	1606 “	0.78
Boiler wash (1 @ $3.07)	—	—	0.06
Water change (@ $2.04)	None	—	0.00
Anti-foam compound (@ 10.6¢ lb. on Eng.	None used	—	0.00
Total boiler conditioning expense per trip			$1.07

CASE I

Previous practice—water change after every odd round trip—boiler wash after every even round trip

Item	*Per Single Trip*		*170 miles*
Terminal blowing	None	—	$0.00
Road blowing (@ 48¾¢ per M Gal.)	160 seconds	850 gallons	0.41
Boiler wash (14 @ $3.07)	—	—	0.83
Water change (13 @ $2.04)	—	—	0.51
Anti-foam compound (@ 10.6¢ per lb. on Eng.)	4 pounds	—	0.43
Total boiler conditioning expense per trip			$2.18

CASE II

30-day operating period—one washout—no water change—28 trips of 490 miles—13720 miles operated

Item	*Per Single Trip*		*490 miles*
Terminal blowing (@ 40¢ per M Gal.)	175 seconds	962 gallons	$0.38
Road blowing (@ 40¢ per M Gal.)	775 “	4262 “	1.67
Boiler washout (1 @ $2.77)	—	—	0.10
Water change (@ $1.68)	—	—	0.00
Anti-foam compound (@ 10.6¢ per lb. on Eng.)	None used	—	0.00
Total boiler conditioning expense per trip			$2.15

CASE II

Previous practice—water change every odd round trip—boiler wash every even round trip—foaming controlled by road blowing and use of boiler compound

Item	*Per Single Trip*		*490 miles*
Terminal blowing	None		$0.00
Road blowing (@ 40¢ per M Gal.)	468	2574 gallons	1.04
Boiler wash (7@ $2.77)	—	—	0.69
Water change (7 @ $1.68)	—	—	0.42
Anti-foam compound (@ 10.6¢ per lb. on Eng.)	8 pounds	—	0.85
Total boiler conditioning expense per trip			$3.00

Both cases show a lower cost for boiler conditioning when operating under the extended washout plan than with the frequent washout and water change. Also, there was an improvement in the boiler condition, there being fewer leaks and cleaner heating surfaces, that insures a more economical fuel performance on line.

Use of Hard, or Scale-Forming Waters

Where it is necessary to use unsoftened waters containing hardness ranging from 10 to 20 grains, with frequent washing being done, a scale deposit normal for the water being used is formed. Washing does not remove that scale and the accumulation in any period of time is equally as heavy as if no washing at all were done. The limiting factor in using hard waters is the time required for the scale deposit to become so heavy as to require bumping of the sheets and stays to prevent leaks and metal burns and to maintain economical fuel performance. This time element will vary with the type and degree of hardness in the waters used, being shorter with waters of high hardness than with waters of lesser hardness. In no case will the scale formation be more rapid with the extended washout period than with frequent washing. Observation of boilers operating under these conditions has shown less scale accumulation when operating 30 days between washouts—no water change—than when they were washed often. Two cases of test operation which showed this are given below:

Test No. I

Mountain type locomotive—passenger service—170 mile district—8840 miles operated—no washout—no water change

Report on boiler after 30-day operation: "The interior of the boiler of Engine .... after the 30-day continuous test without boiler wash, water change, or the use of anti-foam compound, was in first-class condition as regards the condition of scale and the absence of mud."

Test No. 2

Mountain type locomotive—passenger service—490 mile district—13,720 miles operated—no water change—no washout—30 days operation

Report on boiler after 30-day run: "The interior of the boiler of Engine .... after the 30-day continuous test without boiler wash or water change at terminals was in first-class condition as regards the accumulation of scale and mud. There was no accumulation of mud or sludge and the condition of the water surfaces of tubes and sheets was better than at the start of the test."

These two tests, together with similar tests on other operating districts and on yard engines at different terminals, showed so satisfactory in maintaining good boiler conditions that three years ago the entire system was placed on the 30-day washout period operation. Since that time the boiler conditions have consistently shown improvement over conditions prevailing when boilers were washed at frequent intervals.

Mud and Sludge Conditions

When the waters used contain appreciable quantities of mud or they cause the precipitation of considerable sludge within the boiler, this material tends to collect in the water legs of the firebox. If these are permitted to accumulate in excessive quantities there is the possibility of blocking water from the sheets and causing them to overheat. However, the experience of roads over a period of years, using waters direct from streams, with only internal type treatment that does not remove mud and which causes the hardness in the water to precipitate as sludge in the boiler, has shown that under normal mud conditions the blowing done to prevent foaming also keeps the mud and sludge drafted from the boiler. When a heavy mud condition does exist in the water used, there must be no hesitancy in washing often enough to prevent the mud from collecting to a hazardous extent.

Alkali Salts

The salts of sodium and potassium, known as "alkali salts" and also as "foaming salts," are extremely soluble in water and a condition of saturation is never reached in a boiler; so these substances do not settle out of the water but remain dissolved in it. Practically all waters contain more or less of these salts, and the extent to which they are present in a water is the usual gage of the water's tendency to cause foaming. For instance, the water supply that contains 50 grains per gallon of alkali or foaming salts will cause foaming more quickly than will a water that contains only 10 grains per gallon. Each boilerful of water evaporated leaves inside the boiler all the foaming salts that were contained in the water, and the concentration of these salts in the water left will be double that of the original feed water. Suppose a boiler of 5,000 gallons capacity uses a water of 50 grains per gallon foaming salts. By the time 5,000 gallons have been evaporated and the boiler kept filled with more water, the water in the boiler will contain its own 50 grains per gallon plus the 50 grains that were in the water evaporated, making then a concentration in the boiler of 100 grains per gallon. When another 5,000 gallons, or 10,000 gallons in all, have been evaporated another 50 grains will be added to the water in the boiler, or there will be a concentration of 150 grains. That is, the evaporation of 10,000 gallons of this water will produce a concentration of foaming salts in the boiler that will likely produce foaming.

Consider a water containing 10 grains per gallon foaming salts. When 5,000 gallons of this water have been evaporated the concentration will be 20 grains per gallon; after 10,000 gallons, 30 grains; after 15,000 gallons, 40 grains, etc. Each boiler full, or 5,000 gallons, evaporated adds 10 grains to the concentration of foaming salts in the boiler. So that 14 boilerfuls, or 70,000 gallons, of this water will have to be evaporated to reach a concentration of 150 grains per gallon, which is likely to cause foaming.

When the concentration causing foaming has been reached with any water, either the boiler must be emptied of the concentrated water, which is difficult to do midway between terminals, or a part of the high concentration blowout and the water remaining in the boiler diluted by the addition of fresh water from the tender, otherwise foaming will take place. If the boiler foams bad enough and long enough there will be sufficient of the concentrated water thrown from the boiler to act just as if the blowoff valve had been opened, and the foaming will then stop. But it is better to blow the same amount of water through the blowoff than to permit it to blow through the cylinders. Also, the blowing should be done ahead of the foaming as a preventive and not be depended on to act as a cure.

A theory has been advanced to the effect that sometimes the concentration of foaming salts in the boiler becomes so great that the water is not able to absorb and carry away heat fast enough to prevent burning sheets and tubes. Such a theory does not appear to be well founded when operating experiences are considered. It is well known that because of differences in operating conditions locomotive boilers are not able to carry foaming salt concentrations as high as can stationary boilers. There are records of stationary boilers working under high overload with concentrations up to 5,000 and 6,000 grains per gallon. Concentrations of 2,500 and 3,000 grains are not unusual in stationary boilers. If these boilers are able to operate with such concentrations and the water carry away the heat fast enough to prevent burning, then it is not logical nor reasonable to believe that a locomotive boiler will burn from such a cause with a much less concentration. Furthermore, the transmission of heat by a liquid decreases as the viscosity of the liquid increases. Before a viscosity sufficient to appreciably retard heat transmission could be obtained the boiler would become inoperative account foaming. So if this theory is casually examined it quickly becomes untenable.

Equipment for Blowing

In order to secure operation of boilers for continuous long periods between washouts, arrangements must be provided for blowing out whenever and wherever desired. Blow-off valves must be placed at such locations as to draw out a maximum amount of mud and sludge when the valve is opened. There are differences of opinion as to what location is the most effective for this purpose. Some prefer a location in the middle of the front water leg; some locate them in the side water leg near the front corner; others put them in the back corner. Some roads use only one blow-off valve; others use two or more. Some roads connect a perforated pipe across the back mud ring; others run such a pipe along the belly of the boiler; while still others connect flush with the outside sheet. The proponent of each type of installation advises that very satisfactory cleanliness of the boiler is secured.

There are various methods of operating the valves and disposing of the water and steam blown out. Some valves are of the automatic type. One of the most effective of these is electrically operated, controlled by an electrode extending into the boiler steam space and located at a predetermined height above the water line. When foam builds upon the water to reach the electrode the electric current is closed, causing the blow-off valve to open. As soon as the foam drops below the electrode the circuit is broken and the valve closes. Other automatic valves are of the continuous blow type. The valve is operated by steam pressure from the cylinder chest, so that whenever the engine is working the valve is open and a stream of water is being discharged from the boiler. This type of blowing arrangement has an orifice of predetermined satisfactory size set in the discharge pipe to control the amount of water blown out. The continuous type blow can also be used with a manually operated valve. Other systems are operated manually by the enginemen, the valve having a lever connection into the cab for convenience and safety of operation. These valves usually have a discharge of 1½-in. or 2-inch diameter and they are opened at the discretion of the engineman for a few seconds at a time.

The discharge from the boiler can be objectionable if not properly disposed of. In open country it is practical to have a straight side-open discharge, provided discretion is used in operation so that buildings, signal and switch stands, and people are not blown on. Engines operating in switch yards and in passenger service cannot blow this way. The discharge must be controlled so as not to damage structures or injure people. To guard against the occurrence of these conditions, various types of mufflers are used. Some of these take the discharge through a series of plates having small holes through them to break the water into fine particles and discharge it downward or horizontally backward to avoid disturbing ballast of the track. Some mufflers are located under the cab, either between the rails or just outside the rail; others are set under the engine tender and discharge between the rails. Mufflers of the centrifugal type are located on top of the boiler, and the water and steam are separated by centrifugal action, the steam discharging directly overhead while the water is drained to the ground just outside of the end of the ties.

At terminal points where boilers are given terminal blow, those with mufflers are usually blown directly into the cinder pit. Various arrangements are made for taking care of boilers having only the straight side blow. If it is desired to recover the blowdown water, toggles are built for connecting to the blow-off valve and then are piped to the boiler washing plant. Otherwise suitable blow-down boxes or plain walls are erected with drainage connection to a sewer.

One feature stands out prominently through all this. Regardless of the location of the blow-off valve, with or without perforated pipe connection inside the boiler; whether the valve is automatic in operation or manually controlled, fitted with a muffler or blows straight out, if suitable attention is given to the operation of the valve the boiler can be kept clean and foaming prevented for periods of thirty days permitted for locomotive boilers and for indefinite periods for stationary boilers.

Supervision Required

To operate boilers with the extended washout period, competent supervision is as necessary as for any other type of work. It is necessary first to know that the blow-off system is in good condition and will work. Then it is necessary to know that the water in the boiler is being maintained in proper condition. Since foaming is the main feature to guard against, water samples are taken from each boiler entering and leaving terminal and tested to determine the concentration of foaming salts in it. There are two types of instruments used for practical determinations of boiler water concentrations. One is a hydrometer, the float being fitted with a thermometer having a scale for making temperature corrections. The other is a "densimeter" having two parts, one a thermometer calibrated to read direct in grains per gallon and the other a glass bulb. Both are placed in the sample being tested and the thermometer is read just at the time float rises to the top of the sample being tested. While neither instrument is as accurate as a laboratory balance they are sufficiently close for practical operating purposes. Where either of these instruments is used, someone person at the roundhouse should be delegated to test all boiler water samples. The data from inbound boilers is used as a guide to the amount of water to blow from the boilers; the outbound samples are tested to determine that the water is in condition for satisfactory road work.

Objections to Blowing

There are found to be some objections to the blowing of boilers. This is particularly true when the system of operation is first instituted on the road. Some men object to any change from an established practice. If a thing is new they will try to discredit it. Switch stands have been blown down, blow-off valves have been opened so that buildings have been damaged and passenger equipment rendered dirty and unsightly. Some have claimed that discharging the water from boilers onto ties and bridge timbers causes them to rot out very rapidly. This has not been substantiated yet and there is good reason to believe that the claim is not well founded. Also, claims have been made that frequent discharge of boiler water salines on the roadbed produces a condition that shunts and short-circuits signal currents, causing interruption of correct signal indications. While it is possible that this condition is produced, it has not been clearly and definitely established. However, both of these conditions can be readily eliminated by placing the centrifugal separator on top of the boiler and discharging the water outside the track.

Benefits from Blowing Boilers

The benefits from blowing boilers and operating with extended washout period are many and very definite. Probably the first benefit noticed is the decrease in engine failures and train delays account foaming. This trouble is practically eliminated when terminal and road blowing are properly done. If some abnormal and emergency water condition develops that would normally cause a boiler to foam, the engine crew increases the blowing sufficient to take care of the situation and the train operates without delay. This improvement in operation is an intangible item, but it is of very definite benefit. There is a decrease in the cost of terminal engine handling that will run from 25 cents to 50 cents per engine handled. Engines are turned more quickly, keeping them in more nearly continuous service. Fewer engines are required to handle the business at hand, meaning that a smaller number of engines has to be maintained for service.

The greatest tangible saving comes from decreased boiler maintenance cost. Every time a hot boiler is emptied, the sheets, staybolts, and flues cool rapidly. Even though hot water is used for washing and filling, it is cold to the boiler metal with its temperatures of 250 to 300 degrees Fahr. The rapid cooling of the metal is accompanied by rapid contraction and excessive stresses. There is a corresponding expansion, though slower, when the boiler is reheated. Frequent repetition of this cycle soon produces cracks in flue sheet knuckles, in side sheets, and breaks staybolts. One road that formerly had fluesheet knuckles, cracking in five to six months now runs the same engines in the same service for more than twice as long per knuckle patch; side sheets that formerly cracked in ten to fourteen months have had no cracks in the past three years. Another road has a record of less than one broken staybolt per engine per year. One road made a saving in roundhouse boiler maintenance alone of more than $100,000 per year since adopting the operating of boilers on the extended washout period.

Summary

Boiler washing does not prevent:

(1) Scale formation
(2) Corrosion
(3) Development of leaks

Boiler washing can prevent:

(1) Mud accumulation
(2) Foaming

Boiler blowing can prevent:

(1) Mud accumulation
(2) Foaming

Boiler blowing produces:

(1) Extended washout periods
(2) Improvement in train operation
(3) Decreased scale formation in boilers
(4) Decreased boiler leaking conditions
(5) Decreased number of cracked sheets and broken bolts
(6) Decreased terminal handling costs
(7) Improved road fuel performance
(8) Greatly decreased boiler maintenance costs

Conclusions

(1) The presence of excessive amounts of mud and the deposition of scale of sufficient thickness to require bombardment of sheets for removal are the only water conditions that affect the period between boiler washouts providing the boilers are properly blown and handled.

(2) Operation of steam locomotives over extended washout periods by proper use of the blow-off valves is practical and produces large economies for the roads that use this method for conditioning water in boilers.

REPORT OF COMMITTEE III—TIES

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W. J. Burton,
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E. E. Chapman,
S. B. Clements,
R. L. Cook,
E. L. Crugar,
H. R. Duncan,
C. F. Ford,
B. D. Howe,
C. S. Kirkpatrick,
P. A. Kerwin,
J. H. Lauderdale,
L. O. Lower,
A. F. Maischaider,
H. R. Clarke, *Vice-Chairman;*
F. M. Robb,
S. S. Roberts,
J. W. Tate,
Sverre Thorvaldson,
C. D. Turley,
R. C. Young,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual (Appendix A).

(2) Extent of Adherence to Specifications (Appendix B). Current report presented as information.

(3) Substitutes for wooden ties—no report. In view of the demands on railroads for various data and because no new types of tie has been reported, it was decided to omit the questionnaire and statements regarding substitutes for wood for at least a year.

(4) Tie renewal averages and costs per maintained mile, securing data from reports to I.C.C. Statistics for 1934 presented as information in Bulletin 376, June, 1935, page 27.

(5) Proper seasoning of oak ties with special reference to those grown in southern lowlands, collaborating with Committee XVII—Wood Preservation. Progress in study—no report.

(6) Best practice from the manufacture of the tie to its installation in track, collaborating with Committee XVII—Wood Preservation. Progress in study—no report.

(7) Effect of volume of traffic on life of creosoted ties. Progress in study—no report.

(8) Effect of different kinds of ballast on life of ties. Progress in study—no report.

(9) Prepare specifications for pre-adzing and pre-boring cross-ties. Complete, with recommended conclusions for publication in the Manual.

The Committee on Ties,
John Foley, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

John Foley, Chairman, Sub-Committee; R. S. Belcher, H. R. Clarke, W. C. Bolin, W. J. Burton, H. R. Duncan, C. F. Ford, A. F. Maischaider, S. S. Roberts.

CARE OF TIES AFTER DISTRIBUTION

Page 130. Eliminate "S" in the paragraph on "Ironing" because other shapes are used and provided for in the specifications for anti-splitting devices on pages 8–9 of Bulletin 337.

Page 132. Eliminate "and to see that no tie is held in storage longer than one-fifth of its estimated life in track" in the paragraph on "Choosing," because economic necessities rather than physical conditions govern the period of storage for ties, which are now nearly all given preservative treatment.

Bulletin 383, January, 1936.

TABLE A

CROSS TIES LAID IN REPLACEMENT - CLASS I STEAM ROADS UNITED STATES AND LARGE CANADIAN ROADS

Calendar year ended December 31, 1934

Road	Wooden ties untreated (U)		Wooden ties treated (T)		Ties other than wood(S) and second hand	Total ties applied	Miles of maintained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Equated gross ton-miles a
	Number	Average cost	Number	Average cost					
1	2	3	4	5	6	7	8	9	10
NEW ENGLAND REGION:									
Bangor & Aroostook	170 636	$0.62	-	-	-	170 636	835.16	2 388 368	1 405 833 712
Boston & Maine	6 681	0.58	403 502	$1.71	-	410 183	3 490.14	10 060 000	12 764 735 696
Canadian Nat.Lines in New Eng.	9 312	0.72	12 003	1.83	-	21 315	251.60	773 954	379 924 448
Canadian Pacific (lines in Me.)	149	0.36	38 670	1.39	-	38 819	213.01	617 190	1 051 484 936
Canadian Pacific (lines in Vt.)	-	-	8 255	1.44	-	8 255	122.15	416 857	463 238 752
Central Vermont	7 582	0.57	95 274	1.41	-	102 856	532.16	1 636 800	1 954 402 568
Maine Central	120 975	0.76	128 068	1.47	-	249 043	1 295.31	3 928 650	3 078 586 704
New York Connecting	-	-	6 664	1.60	-	6 664	25.98	82 861	286 203 064
New York,New Haven & Hartford	-	-	292 664	1.37	-	292 664	4 685.03	13 423 405	17 566 418 880
Rutland	-	-	67 864	1.04	-	67 864	524.37	1 577 455	1 543 807 728
GREAT LAKES REGION:									
Ann Arbor	-	-	44 273	1.33	-	44 273	416.53	1 241 366	1 233 475 392
Cambria & Indiana	20 667	0.87	-	-	-	20 667	60.61	166 600	125 064 000
Delaware & Hudson	601	1.08	152 212	2.02	(S) 15 587	168 400	1 489.52	4 505 797	7 951 069 848
Delaware,Lackawanna & Western	41 169	0.34	222 863	1.34	-	264 032	2 435.45	7 062 805	15 404 268 568
Detroit & Mackinac	19 115	0.39	10 630	0.92	* 32	29 777	295.16	885 471	218 476 544
Detroit & Toledo Shore Line	-	-	12 528	1.65	* 370	12 898	151.55	461 824	611 495 000
Erie (Inc.Chgo.& Erie)	287	0.83	522 473	1.39	-	522 760	5 030.13	14 586 676	32 200 337 208
Grand Trunk Western	125 482	1.01	170 663	1.43	-	296 145	1 949.86	6 161 541	6 290 051 320
Lehigh & Hudson River	-	-	2 895	1.77	* 1 116	4 011	127.37	335 500	568 248 184
Lehigh & New England	1 175	0.55	20 986	1.74	-	22 161	293.68	881 184	805 839 672
Lehigh Valley	-	-	194 305	1.43	-	194 305	2 964.67	8 691 467	14 852 873 616
Monongahela	527	1.00	37 788	1.80	-	38 315	246.84	711 252	809 694 896
Montour	2 219	1.26	6 988	2.09	-	9 207	79.95	224 088	253 950 000
New Jersey & New York	-	-	4 685	1.21	-	4 685	57.04	164 512	248 313 400
New York Central	3 885	1.29	1 735 835	1.45	* 24 198	1 763 918	24 864.05	70 303 081	126 736 554 344
New York,Chicago & St.Louis	-	-	b 215 289	1.79	-	215 289	2 552.73	8 005 000	14 281 228 680
New York,Ontario & Western	828	0.51	61 588	1.21	-	62 416	910.94	2 580 603	3 320 503 184
New York,Susquehanna & Western	-	-	43 438	1.31	-	43 438	335.02	967 746	547 162 328
Pere Marquette	19 494	0.19	330 949	1.41	-	350 443	2 854.47	8 565 125	9 377 903 904
Pittsburgh & Lake Erie	50	1.58	38 257	1.88	-	38 307	945.74	2 833 418	3 574 418 888
Pittsburg & Shawmut	29 112	0.80	3 720	1.89	-	32 832	126.34	351 202	169 162 984
Pittsburgh & West Virginia	38 065	1.00	-	-	-	38 065	203.47	590 051	601 187 000
Pittsburg,Shawmut & Northern	21 546	0.87	20 983	1.87	-	42 529	232.56	675 967	269 241 112
Wabash	3 344	0.94	426 792	1.47	-	430 136	3 321.47	10 296 808	16 967 058 728
CENTRAL EASTERN REGION:									
Akron,Canton & Youngstown	56 425	1.26	-	-	-	56 425	213.68	615 396	343 652 056
Baltimore & Ohio	36 962	1.25	843 144	1.64	-	880 106	10 853.76	30 263 990	53 699 467 064
Bessemer & Lake Erie	821	0.94	122 843	2.09	(S) 604	124 268	514.07	1 593 800	2 149 434 384
Central R.R.of New Jersey	-	-	49 115	1.65	-	49 115	1 507.86	4 244 970	7 133 470 928
Chicago & Eastern Illinois	17	1.22	151 898	1.12	-	151 915	1 549.23	4 804 007	5 385 749 152
Chicago & Illinois Midland	-	-	10 162	1.25	-	10 162	159.58	492 500	757 830 568
Chicago,Indianapolis & Louisville	102	0.68	72 347	1.02	* 2 575	75 024	888.29	2 736 727	3 044 366 064
Detroit,Toledo & Ironton	-	-	87 078	1.21	-	87 078	614.54	1 769 875	1 486 453 672
Elgin,Joliet & Eastern	735	0.81	148 768	1.38	* 1 725	151 228	906.24	2 796 588	2 124 006 000
Illinois Terminal	14 344	0.71	36 604	1.02	* 18 455	69 403	694.54	1 868 313	1 195 237 400
Long Island	-	-	54 334	1.60	-	54 334	844.65	2 493 734	6 325 414 864
Missouri-Illinois	72 310	0.57	255	1.01	-	72 565	245.31	758 050	213 652 440
Pennsylvania	165	0.88	1 402 699	1.56	c 1 707	1 404 571	21 897.07	61 309 964	135 019 576 480
Penna.-Reading Seashore Lines	-	-	39 307	1.34	-	39 307	700.59	1 915 908	1 850 609 248
Reading Co.	-	-	105 992	1.74	-	105 992	3 059.08	8 384 563	14 253 725 176
Staten Island Rapid Transit	-	-	7 064	2.54	-	7 064	102.58	282 038	359 629 776
Western Maryland	58 717	0.70	205 330	1.32	-	264 047	1 204.91	3 470 150	4 929 149 440
Wheeling & Lake Erie	1 328	0.89	53 338	1.35	* 4 472	59 138	864.76	2 605 207	2 853 281 936
POCAHONTAS REGION:									
Chesapeake & Ohio	-	-	488 487	1.10	(S) 127	488 614	5 172.90	15 901 972	45 229 664 976
Norfolk & Western	-	-	390 073	1.13	* 104 382	494 455	4 321.14	13 395 534	29 794 021 000
Richmond,Fredericksburg & Potomac	130 177	0.76	-	-	* 368	130 545	378.97	1 085 000	2 765 705 696
Virginian	52 841	0.66	124 562	1.24	* 1 323	178 726	854.53	2 661 006	5 057 077 704
SOUTHERN REGION:									
Alabama Great Southern	30 161	1.00	120 279	1.27	-	150 440	546.56	1 695 718	2 243 752 656
Atlanta & West Point	35	0.69	21 407	1.49	-	21 422	141.53	432 556(	1 074 416 296
Western Ry.of Alabama	208	0.79	21 888	1.45	-	22 096	184.36	558 201(	
Atlanta,Birmingham & Coast	120 601	0.72	96	1.18	-	120 697	796.75	2 302 450	1 340 060 440
Atlantic Coast Line	958 274	0.77	40 076	1.02	-	998 350	6 883.98	19 994 520	17 836 912 672
Central of Georgia	9 052	0.55	293 966	0.71	-	303 018	2 513.78	7 052 300	6 317 560 208
Charleston & Western Carolina	69 661	0.98	-	-	-	69 661	427.85	1 248 749	660 905 800
Cincinnati,New Orleans & Tex.Pac.	220	0.47	127 140	1.44	-	127 360	781.30	2 428 912	5 362 008 840
Clinchfield	98 030	0.72	28 455	1.36	-	126 485	402.95	1 224 977	2 071 491 152
Columbus & Greenville	13 622	0.57	31 163	1.04	-	44 785	203.88	645 892	309 005 744
Florida East Coast	201 059	0.75	-	-	-	201 059	1 493.60	4 294 911	3 399 207 680
Georgia R.R.	45 643	0.98	11 859	1.44	-	57 502	432.07	1 323 855	1 259 488 776
Georgia & Florida	119 694	0.51	-	-	-	119 694	450.54	1 216 458	348 003 560
Georgia,Southern & Florida	47 023	0.69	-	-	-	47 023	474.61	1 491 230	1 044 152 480
Gulf & Ship Island	53 146	0.44	2 378	0.94	* 173	55 697	324.01	992 513	417 469 008
Gulf,Mobile & Northern	31 696	0.46	121 160	0.84	* 2 243	155 099	972.97	3 082 369	1 957 047 680
Illinois Central	183 842	0.51	884 048	0.99	* 4 655	1 072 545	7 934.74	24 152 890(	42 898 431 768
Yazoo & Miss.Valley	95 135	0.52	171 341	1.01	* 216	266 692	2 173.96	6 639 098(	
Louisville & Nashville	66 790	0.98	713 963	1.25	-	780 753	7 119.96	20 341 489	30 449 465 800
Mississippi Central	2 582	0.43	23 682	1.02	-	26 264	169.73	535 305	183 640 104
Mobile & Ohio	387 534	0.68	-	-	-	387 534	1 223.75	3 873 070	3 842 321 744
Nashville,Chattanooga & St.Louis	18 298	0.43	264 516	1.04	-	282 814	1 635.00	4 827 867	5 479 225 000
New Orleans & Northeastern	17 626	0.97	38 384	1.22	-	56 010	285.89	887 322	1 049 838 336
Norfolk Southern	420 438	0.58	-	-	-	420 438	1 089.53	3 099 174	1 359 151 512
Northern Alabama	44 931	0.83	-	-	-	44 931	123.56	390 696	185 805 800
Seaboard Air Line	672 557	0.74	562 073	0.86	-	1 234 630	5 752.59	16 104 600	15 314 962 832
Southern Ry.	2 051 555	0.90	447 241	1.28	-	2 498 796	8 861.29	27 697 763	32 822 323 248
Tennessee Central	100 681	0.67	8 066	1.74	-	108 747	334.87	1 048 797	696 780 176

TABLE A

CROSS TIES LAID IN REPLACEMENT - CLASS I STEAM

Calendar year ended Dece

Road	Wooden ties untreated (U)		Wooden ties treated (T)	
	Number	Average cost	Number	Average cost

Chicago,Indianapolis & Louisville	888.29	3 081	72 449
Detroit,Toledo & Ironton	614.54	2 880	87 078
Elgin,Joliet & Eastern	906.24	3 086	149 503
Illinois Terminal	694.54	2 690	50 948
Long Island	844.65	2 952	54 334
Missouri-Illinois	245.31	3 090	72 565
Pennsylvania	21 897.07	2 800	1 402 864

Sheet 2 of 2 sheets

TABLE A

CROSS TIES LAID IN REPLACEMENT - CLASS I STEAM ROADS UNITED STATES AND LARGE CANADIAN ROADS

Calendar year ended December 31, 1934

Road	Wooden ties untreated (U)		Wooden ties treated (T)		Ties other than wood(S) and second hand	Total ties applied	Miles of maintained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Equated gross ton-miles a
	Number	Average cost	Number	Average cost					
1	2	3	4	5	6	7	8	9	10
NORTHWESTERN REGION:									
Chicago & North Western	99 090	$0.46	1 352 094	$1.00	-	1 451 184	12 500.04	36 799 634	34 016 999 776
Chicago Great Western	99 106	0.89	280 171	1.15	-	379 277	1 959.67	5 647 162	7 994 985 864
Chicago,Milwaukee,St.Paul & Pacific	849 460	0.42	1 850 333	1.14	-	2 699 793	14 647.08	43 505 407	39 816 636 528
Chicago,St.Paul,Minpls.& Omaha	91 620	0.42	279 401	1.02	-	371 021	2 266.85	6 713 560	6 681 230 784
Duluth,Missabe & Northern	17 223	0.60	57 614	1.75	-	74 837	1 204.73	3 607 363	1 734 714 008
Duluth,South Shore & Atlantic	89 825	0.52	5	1.42	-	89 830	558.71	1 590 579	680 068 696
Duluth,Winnipeg & Pacific	79 739	0.47	-	-	-	79 739	212.71	638 100	330 999 168
Great Northern	92 437	0.40	1 023 411	1.11	* 19 035	1 134 883	10 155.18	32 581 063	28 087 262 112
Green Bay & Western	98 534	0.62	-	-	-	98 534	289.69	811 132	344 851 856
Lake Superior & Ishpeming	44 240	0.55	-	-	-	44 240	237.62	712 860	136 039 896
Minneapolis & St.Louis	97 966	0.71	93 246	1.15	-	191 212	1 845.37	5 558 445	3 066 064 104
Minneapolis,St.Paul & S.S.Marie	406 855	0.54	392 295	1.12	-	799 150	5 068.51	14 920 530	9 435 937 344
Northern Pacific	46 877	0.47	703 470	1.12	-	750 347	9 116.37	26 463 481	22 100 452 336
Oregon-Washington R.R.& Nav.Co	5 365	0.44	256 456	0.97	-	261 821	2 205.66	6 408 225	5 422 989 216
Spokane International	60 918	0.44	-	-	-	60 918	194.32	549 145	159 302 856
Spokane,Portland & Seattle	94 813	0.47	823	1.15	-	95 636	671.26	2 013 780	2 030 982 592
CENTRAL WESTERN REGION:									
Alton R.R.	378 815	1.07	25 509	1.72	* 6 828	411 152	1 536.64	4 631 966	5 736 705 656
Atchison,Topeka & Santa Fe	1 646	0.65	1 862 446	1.09	-	1 864 092	19 291.07	58 586 978	61 668 182 952
Chicago,Burlington & Quincy	-	-	1 143 346	1.20	* 126 358	1 269 704	12 555.26	38 770 643	39 625 487 784
Chicago,Rock Island & Pacific	1 419	0.41	601 685	1.02	-	603 104	9 828.60	29 504 186(	31 520 758 248
Chicago,Rock Island & Gulf	-	-	58 901	1.61	* 7 546	66 447	844.19	2 621 121(	
Colorado & Southern	82 414	0.42	89 707	1.17	* 11 890	184 011	1 127.91	3 413 202	2 225 441 872
Denver & Rio Grande Western	3 877	0.32	572 522	1.01	n 166 258	742 657	3 449.05	10 705 408	8 677 398 416
Denver & Salt Lake	42 368	0.75	14 956	0.96	-	57 324	300.45	920 904	454 046 424
Fort Worth & Denver City	-	-	32 383	1.08	-	32 383	968.25	2 910 560	2 193 748 408
Los Angeles & Salt Lake	4 727	0.89	244 506	1.30	-	249 233	1 498.23	4 206 039	6 638 464 304
Nevada Northern	24 653	0.75	-	-	-	24 653	190.83	547 695	83 720 320
Northwestern Pacific	65 498	0.53	471	0.87	-	65 969	484.75	1 427 139	918 413 728
Oregon Short Line	256	0.67	358 495	1.17	-	358 751	3 322.38	9 215 258	9 123 300 408
St.Joseph & Grand Island	451	0.55	54 669	1.77	-	55 120	333.71	987 784	1 304 376 096
San Diego & Arizona Eastern	24 679	0.78	-	-	-	24 679	168.72	498 006	138 709 288
Southern Pacific Co.- Pac.Lines	102 389	0.61	719 214	1.07	* 180 430	1 002 033	12 579.99	37 220 532	51 293 896 152
Toledo,Peoria & Western	13 902	0.79	56 275	1.31	-	70 177	273.84	867 525	620 623 168
Union Pacific	610	0.95	754 956	1.28	-	755 566	5 997.00	16 923 300	38 371 885 824
Utah Ry.	8 122	0.69	6 634	1.77	-	14 756	89.15	231 790	182 046 000
Western Pacific	402 733	0.63	28	1.17	-	402 761	1 469.33	4 289 600	6 169 757 064
SOUTHWESTERN REGION:									
Burlington-Rock Island	-	-	13 495	0.68	-	13 495	242.79	759 933	382 008 448
Fort Smith & Western	67 732	0.50	-	-	-	67 732	235.90	734 284	249 680 256
Fort Worth & Rio Grande	35 052	0.81	395	1.08	-	35 447	245.39	777 396	219 795 656
Gulf Coast Lines:									
Beaumont,Sour Lake & Western	-	-	15 506	0.99	-	15 506	141.04	419 700(	3 942 005 296
New Orleans,Texas & Mexico	-	-	23 274	1.01	-	23 274	224.23	686 100(	
St.Louis,Brownsville & Mexico	-	-	31 735	0.91	-	31 735	707.90	2 150 100(	
San Antonio,Uvalde & Gulf	-	-	28 029	1.00	-	28 029	365.99	1 054 500(	
International-Great Northern	230	0.77	169 230	0.86	-	169 460	1 516.89	4 540 100	5 732 790 848
~~Kansas City Southern~~	18	0.47	137 490	0.91	-	137 508	1 263.95	4 004 585	3 549 630 712
Kansas,Oklahoma & Gulf	-	-	75 943	0.93	-	75 943	365.61	1 163 736	706 565 176
Louisiana & Arkansas	80 756	0.49	100 424	0.74	-	181 180	722.51	2 284 350	1 418 568 200
Louisiana,Arkansas & Texas	86 738	0.46	216	1.20	-	86 954	245.60	743 419	336 960 032
Midland Valley	-	-	40 163	0.99	-	40 163	415.99	1 331 168	364 286 224
Missouri & North Arkansas	118 581	0.47	-	-	-	118 581	362.45	1 129 480	389 880 232
Missouri-Kansas-Texas Lines	82 807	0.66	439 876	1.16	-	522 683	4 104.26	12 925 700	13 091 430 664
Missouri Pacific	214 937	0.52	1 337 856	0.95	-	1 552 793	9 213.04	28 549 100	37 158 755 280
Oklahoma City-Ada-Atoka	14 365	0.54	3 661	1.27	-	18 026	151.32	474 750	80 514 152
St.Louis-San Francisco	69 047	0.55	1 294 270	1.00	-	1 363 317	6 743.73	21 166 201	17 765 761 304
St.Louis,San Francisco & Texas	79 200	0.81	28 834	1.16	-	108 034	252.83	800 965	294 784 936
St.Louis Southwestern Lines	602	0.24	144 698	1.19	* 235	145 535	2 011.53	6 369 795	5 962 281 600
Texas & New Orleans	82 617	0.92	615 341	0.67	-	697 958	5 766.58	15 672 785	14 223 104 832
Texas & Pacific	74	0.31	198 092	0.82	-	198 166	2 529.57	7 453 872	9 933 180 152
Texas Mexican	-	-	31 345	1.06	* 633	31 978	205.65	592 278	216 178 504
Wichita Falls & Southern	-	-	33 762	0.83	-	33 762	196.62	648 846	112 582 728
CANADIAN ROADS:									
Canadian National d	2 443 563	0.48	3 534 141	1.27	-	5 977 704	30 221.00	86 590 000	61 632 300 000
Canadian Pacific	1 693 168	0.49	1 928 166	1.09	-	3 621 334	21 788.00	61 836 687	48 708 351 022
Temiskaming & Nortnern Ontario	156 159	0.69	-	-	-	156 159	637.21	1 814 200	957 719 616

a Maishaider formula.
b Includes second hand ties.
c Tie blocks.
n Indicates narrow gauge ties.
* All second hand ties.

NOTE: Compiled from annual reports of Class I steam roads to the Interstate Commerce Commission.

d Includes lines in New England, Grand Trunk Western and Duluth,Winnipeg & Pacific.

TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) ON

Calendar year ended Dece

NOTE: All figures are exclusive of

	Miles of maintained track	Average number of wooden cross ties	Total number of wooden
[illegible]	[illegible]	3 060	23 274
St.Louis,Brownsville & Mexico	707.90	3 037	31 739
San Antonio,Uvalde & Gulf	365.99	2 881	28 029
International-Great Northern	1 516.89	2 993	169 460
Kansas City Southern	1 263.95	3 168	137 508
Kansas,Oklahoma & Gulf	365.61	3 183	75 943
Louisiana & Arkansas	722.51	3 162	181 180
Louisiana,Arkansas & Texas	245.60	3 027	86 954
Midland Valley	415.99	3 200	40 163

Sheet 1 of 2 sheets

TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) ON LEADING RAILROADS IN THE UNITED STATES AND CANADA

Calendar year ended December 31, 1934

NOTE: All figures are exclusive of bridge & switch ties

Road	Miles of maintained track occupied by wooden cross ties (Col.8-Table A)	Average number of wooden cross ties per mile of maintained track	Total number of wooden cross ties renewed 1934	Number of wooden cross ties renewed per mile of maintained track	Weighted average cost per wooden cross tie	Cost of wooden cross tie renewals per mile of maintained track	Per cent wooden cross tie renewals to all ties in tracks	Equated gross ton-miles per mile of maintained track	Cost of wooden cross tie renewals per thousand equated gross ton-miles
1	2	3	4	5	6	7	8	9	10
NEW ENGLAND REGION:									
Bangor & Aroostook	835.16	2 860	170 636	204	$0.62	$127	7.1	1 683 311	$.075
Boston & Maine	3 490.14	2 882	410 183	118	1.69	198	4.1	3 657 371	.054
Canadian Nat.Lines in New Eng.	251.60	3 076	21 315	85	1.35	114	2.8	1 510 034	.076
Canadian Pacific (lines in Me.)	213.01	2 897	38 819	182	1.39	252	6.3	4 936 317	.051
Canadian Pacific (lines in Vt.)	122.15	3 413	8 255	68	1.44	98	2.0	3 792 376	.026
Central Vermont	532.16	3 076	102 856	193	1.35	261	6.3	3 672 585	.071
Maine Central	1 295.31	3 033	249 043	192	1.12	216	6.3	2 376 718	.091
New York Connecting	25.98	3 189	6 664	257	1.60	411	8.0	11 016 284	.037
New York,New Haven & Hartford	4 685.03	2 865	292 664	62	1.37	85	2.2	3 749 478	.023
Rutland	524.37	3 008	67 864	129	1.04	134	4.3	2 944 119	.046
GREAT LAKES REGION:									
Ann Arbor	416.53	2 980	44 273	106	1.33	141	3.6	2 961 312	.048
Cambria & Indiana	60.61	2 749	20 667	341	0.87	296	12.4	2 063 422	.143
Delaware & Hudson	1 489.52	3 025	152 813	103	2.01	206	3.4	5 338 008	.039
Delaware,Lackawanna & Western	2 435.45	2 900	264 032	108	1.18	128	3.7	6 325 019	.020
Detroit & Mackinac	295.16	3 000	29 745	101	0.58	58	3.4	740 197	.079
Detroit & Toledo Shore Line	151.55	3 047	12 528	83	1.65	137	2.7	4 034 939	.034
Erie (Incl.Chgo.& Erie)	5 030.13	2 900	522 760	104	1.39	144	3.6	6 401 492	.023
Grand Trunk Western	1 949.86	3 160	296 145	152	1.25	190	4.8	3 225 899	.059
Lehigh & Hudson River	127.37	2 634	2 895	23	1.77	40	0.9	4 461 397	.009
Lehigh & New England	293.68	3 000	22 161	75	1.68	127	2.5	2 743 938	.046
Lehigh Valley	2 964.67	2 932	194 305	66	1.43	94	2.2	5 009 958	.019
Monongahela	246.84	2 881	38 315	155	1.79	278	5.4	3 280 242	.085
Montour	79.95	2 803	9 207	115	1.89	218	4.1	3 176 360	.069
New Jersey & New York	57.04	2 884	4 685	82	1.21	100	2.8	4 353 320	.023
New York Central	24 864.05	2 827	1 739 720	70	1.45	102	2.5	5 097 181	.020
New York,Chicago & St.Louis	2 552.73	3 136	215 289	84	1.79	151	2.7	5 594 492	.027
New York,Ontario & Western	910.94	2 833	62 416	69	1.20	82	2.4	3 645 139	.023
New York,Susquehanna & Western	335.02	2 889	43 438	130	1.31	170	4.5	1 633 223	.104
Pere Marquette	2 854.47	3 001	350 443	123	1.34	164	4.1	3 285 340	.050
Pittsburgh & Lake Erie	945.74	2 996	38 307	41	1.88	76	1.4	3 779 494	.020
Pittsburg & Shawmut	126.34	2 780	32 832	260	0.93	241	9.3	1 338 950	.180
Pittsburgh & West Virginia	203.47	2 900	38 065	187	1.00	186	6.5	2 954 671	.063
Pittsburg,Shawmut & Northern	232.56	2 907	42 529	183	1.36	249	6.3	1 157 728	.215
Wabash	3 321.47	3 100	430 136	130	1.47	190	4.2	5 108 298	.037
CENTRAL EASTERN REGION:									
Akron,Canton & Youngstown	213.68	2 880	56 425	264	1.26	333	9.2	1 608 256	.207
Baltimore & Ohio	10 853.76	2 788	880 106	81	1.63	132	2.9	4 947 545	.027
Bessemer & Lake Erie	514.07	3 100	123 664	241	2.08	501	7.8	4 181 210	.120
Central R.R.of New Jersey	1 507.86	2 815	49 115	33	1.65	54	1.2	4 730 858	.011
Chicago & Eastern Illinois	1 549.23	3 101	151 915	98	1.12	109	3.2	3 476 404	.031
Chicago & Illinois Midland	159.58	3 086	10 162	64	1.25	80	2.1	4 748 907	.017
Chicago,Indianapolis & Louisville	888.29	3 081	72 449	82	1.02	83	2.6	3 427 221	.024
Detroit,Toledo & Ironton	614.54	2 880	87 078	142	1.21	172	4.9	2 418 807	.071
Elgin,Joliet & Eastern	906.24	3 086	149 503	165	1.38	227	5.3	2 343 757	.097
Illinois Terminal	694.54	2 690	50 948	73	0.93	68	2.7	1 720 905	.040
Long Island	844.65	2 952	54 334	64	1.60	103	2.2	7 488 800	.014
Missouri-Illinois	245.31	3 090	72 565	296	0.57	168	9.6	870 949	.193
Pennsylvania	21 897.07	2 800	1 402 864	64	1.56	100	2.3	6 166 102	.016
Penna.-Reading S.S.Lines	700.59	2 735	39 307	56	1.34	75	2.1	2 641 501	.028
Reading Co.	3 059.08	2 741	105 992	35	1.74	60	1.3	4 659 481	.013
Staten Island Rapid Transit	102.58	2 749	7 064	69	2.54	175	2.5	3 505 847	.050
Western Maryland	1 204.91	2 880	264 047	219	1.18	260	7.6	4 090 886	.063
Wheeling & Lake Erie	864.76	3 013	54 666	63	1.34	85	2.1	3 299 507	.026
POCAHONTAS REGION:									
Chesapeake & Ohio	5 172.90	3 074	488 487	94	1.10	104	3.1	8 743 580	.012
Norfolk & Western	4 321.14	3 100	390 073	90	1.13	102	2.9	6 894 945	.015
Richmond,Fred.& Potomac	378.97	2 863	130 177	344	0.76	260	12.0	7 297 954	.036
Virginian	854.53	3 114	177 403	208	1.06	221	6.7	5 917 964	.037
SOUTHERN REGION:									
Alabama Great Southern	546.56	3 103	150 440	275	1.22	335	8.9	4 105 227	.082
Atlanta & West Point	141.53	3 056	21 422	151	1.49	225	5.0)	3 296 868	.059
Western Ry.of Ala.	184.36	3 028	22 096	120	1.44	173	4.0)		
Atlanta,Birmingham & Coast	796.75	2 890	120 697	151	0.72	110	5.2	1 681 908	.065
Atlantic Coast Line	6 883.98	2 905	998 350	145	0.78	114	5.0	2 591 076	.044
Central of Georgia	2 513.78	2 805	303 018	121	0.71	85	4.3	2 513 171	.034
Charleston & Western Carolina	427.85	2 919	69 661	163	0.98	159	5.6	1 544 714	.103
Cincinnati,New Orleans & Tex.Pac.	781.30	3 109	127 360	163	1.44	235	5.2	6 862 932	.034
Clinchfield	402.95	3 040	126 485	314	0.87	272	10.3	5 140 814	.053
Columbus & Greenville	203.88	3 168	44 785	220	0.90	198	6.9	1 515 626	.130
Florida East Coast	1 493.60	2 876	201 059	135	0.75	102	4.7	2 275 849	.045
Georgia R.R.	432.07	3 064	57 502	133	1.07	143	4.3	2 915 011	.049
Georgia & Florida	450.54	2 700	119 694	266	0.51	136	9.8	772 414	.177
Georgia,Southern & Florida	474.61	3 142	47 023	99	0.69	69	3.2	2 200 022	.031
Gulf & Ship Island	324.01	3 063	55 524	171	0.46	78	5.6	1 288 445	.061
Gulf,Mobile & Northern	972.97	3 168	152 856	157	0.76	120	5.0	2 011 416	.060
Illinois Central	7 934.74	3 044	1 067 890	135	0.90	122	4.4)	4 243 714	.028
Yazoo & Mississippi Valley	2 173.96	3 054	266 476	123	0.83	102	4.0)		
Louisville & Nashville	7 119.96	2 857	780 753	110	1.22	134	3.8	4 276 634	.031
Mississippi Central	169.73	3 154	26 264	155	0.96	148	4.9	1 081 954	.137
Mobile & Ohio	1 223.75	3 165	387 534	317	0.68	214	10.0	3 139 793	.068
Nashville,Chattanooga & St.Louis	1 635.00	2 953	282 814	173	1.00	173	5.9	3 351 208	.052
New Orleans & Northeastern	285.89	3 104	56 010	196	1.14	224	6.3	3 672 176	.061
Norfolk Southern	1 089.53	2 845	420 438	386	0.58	224	13.6	1 247 466	.180
Northern Alabama	123.56	3 162	44 931	364	0.83	301	11.5	1 503 770	.200
Seaboard Air Line	5 752.59	2 800	1 234 630	215	0.80	171	7.7	2 662 273	.064
Southern Ry.	8 861.29	3 126	2 498 796	282	0.97	273	9.0	3 704 012	.074
Tennessee Central	334.87	3 132	108 747	325	0.75	242	10.4	2 080 748	.117

TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) O

Calendar year ended Dec

NOTE: All figures are exclusive

Road	Miles of maintained track occupied by	Average number of wooden cross ties per	Total number o wooden cross tie

TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) ON LEADING RAILROADS IN THE UNITED STATES AND CANADA

Calendar year ended December 31, 1934

NOTE: All figures are exclusive of bridge & switch ties

Road	Miles of maintained track occupied by wooden cross ties (Col.8-TableA)	Average number of wooden cross ties per mile of maintained track	Total number of wooden cross ties renewed 1934	Number of wooden cross ties renewed per mile of maintained track	Weighted average cost per wooden cross ties	Cost of wooden cross tie renewals per mile of maintained track	Per cent wooden cross tie renewals to all ties in tracks	Equated gross ton-miles per mile of maintained tracks	Cost of wooden cross tie renewals per thousand equated gross ton-miles
1	2	3	4	5	6	7	8	9	10
NORTHWESTERN REGION:									
Chicago & North Western	12 500.04	2 944	1 451 164	116	$0.96	$111	3.9	2 721 351	$.041
Chicago Great Western	1 959.67	2 882	379 277	194	1.08	209	6.7	4 079 761	.051
Chicago,Milwaukee,St.Paul & Pacific	14 647.08	2 970	2 699 793	184	0.91	168	6.2	2 718 401	.062
Chicago,St.Paul,Minpls.& Omaha	2 266.85	2 962	371 021	164	0.87	143	5.5	2 947 363	.048
Duluth,Missabe & Northern	1 204.73	2 994	74 837	62	1.49	92	2.1	1 439 919	.064
Duluth,South Shore & Atlantic	558.71	2 847	89 830	161	0.52	84	5.6	1 217 212	.069
Duluth,Winnipeg & Pacific	212.71	3 000	79 739	375	0.47	177	12.5	1 556 105	.114
Great Northern	10 155.18	3 208	1 115 848	110	1.05	115	3.4	2 765 806	.042
Green Bay & Western	289.69	2 800	98 534	340	0.62	212	12.1	1 190 417	.178
Lake Superior & Ishpeming	237.62	3 000	44 240	186	0.55	102	6.2	572 510	.178
Minneapolis & St.Louis	1 845.37	3 012	191 212	104	0.92	95	3.4	1 661 490	.057
Minneapolis,St.Paul & S.S.Marie	5 068.51	2 944	799 150	158	0.83	130	5.4	1 861 679	.070
Northern Pacific	9 116.37	2 903	750 347	82	1.08	89	2.8	2 424 260	.037
Oregon-Washington R.R.& Nav.Co.	2 205.66	2 905	261 821	119	0.96	114	4.1	2 458 670	.046
Spokane International	194.32	2 826	60 918	313	0.44	137	11.1	819 797	.168
Spokane,Portland & Seattle	671.26	3 000	95 636	142	0.48	68	4.7	3 025 627	.022
CENTRAL WESTERN REGION:									
Alton R.R.	1 536.64	3 014	404 324	263	1.11	293	8.7	3 733 279	.079
Atchison,Topeka & Santa Fe	19 291.07	3 037	1 864 092	97	1.08	105	3.2	3 196 722	.033
Chicago,Burlington & Quincy	12 555.26	3 088	1 143 346	91	1.20	109	2.9	3 156 087	.035
Chicago,Rock Island & Pacific	9 828.60	3 002	603 104	61	1.02	63	2.0)	2 953 376	.023
Chicago,Rock Island & Gulf	844.19	3 105	58 901	70	1.61	112	2.2)		
Colorado & Southern	1 127.91	3 026	162 121	144	0.86	123	4.7	1 973 067	.062
Denver & Rio Grande Western	3 449.05	3 104	576 399	167	1.01	168	5.4	2 515 881	.067
Denver & Salt Lake	300.45	3 065	57 324	191	0.81	154	6.2	1 511 221	.102
Fort Worth & Denver City	968.25	3 006	32 383	33	1.08	36	1.1	2 265 684	.016
Los Angeles & Salt Lake	1 498.23	2 807	249 233	166	1.29	215	5.9	4 430 871	.048
Nevada Northern	190.83	2 870	24 653	129	0.75	96	4.5	438 717	.220
Northwestern Pacific	484.75	2 944	65 969	136	0.54	73	4.6	1 894 613	.038
Oregon Short Line	3 322.38	2 774	358 751	108	1.16	126	3.9	2 746 014	.046
St.Joseph & Grand Island	333.71	2 960	55 120	165	1.76	291	5.6	3 908 711	.074
San Diego & Arizona Eastern	168.72	2 952	24 679	146	0.78	115	5.0	822 127	.139
Southern Pacific Co.- Pacific Lines	12 579.99	2 959	821 603	65	1.01	66	2.2	4 077 419	.016
Toledo,Peoria & Western	273.84	3 168	70 177	256	1.21	309	8.1	2 266 371	.136
Union Pacific	5 997.00	2 822	755 566	126	1.28	161	4.5	6 398 514	.025
Utah Ry.	89.15	2 600	14 756	166	1.17	194	6.4	2 042 019	.095
Western Pacific	1 469.33	2 919	402 761	274	0.63	172	9.4	4 199 027	.041
SOUTHWESTERN REGION:									
Burlington-Rock Island	242.79	3 130	13 495	56	0.68	38	1.8	1 573 411	.024
Fort Smith & Western	235.90	3 113	67 732	287	0.50	143	9.2	1 058 416	.135
Fort Worth & Rio Grande	245.39	3 168	35 447	144	0.82	118	4.6	895 699	.132
Gulf Coast Lines:									
Beaumont,Sour Lake & Western	141.04	2 976	15 506	110	0.99	109	3.7)	2 739 101	.024
New Orleans,Texas & Mexico	224.23	3 060	23 274	104	1.01	105	3.4)		
St.Louis,Brownsville & Mexico	707.90	3 037	31 735	45	0.91	41	1.5)		
San Antonio,Uvalde & Gulf	365.99	2 881	28 029	77	1.00	76	2.7)		
International-Great Northern	1 516.89	2 993	169 460	112	0.86	96	3.7	3 779 306	.025
Kansas City Southern	1 263.95	3 168	137 508	109	0.91	99	3.4	2 808 363	.035
Kansas,Oklahoma & Gulf	365.61	3 183	75 943	208	0.93	193	6.5	1 932 565	.100
Louisiana & Arkansas	722.51	3 162	181 180	251	0.63	157	7.9	1 963 389	.080
Louisiana,Arkansas & Texas	245.60	3 027	86 954	354	0.46	164	11.7	1 371 987	.120
Midland Valley	415.99	3 200	40 163	97	0.99	96	3.0	875 709	.109
Missouri & North Arkansas	362.45	3 116	118 581	327	0.47	154	10.5	1 075 680	.143
Missouri-Kansas-Texas Lines	4 104.26	3 149	522 683	127	1.08	138	4.0	3 189 718	.043
Missouri Pacific	9 213.04	3 099	1 552 793	169	0.89	150	5.4	4 033 278	.037
Oklahoma City-Ada-Atoka	151.32	3 137	18 026	119	0.69	82	3.8	532 079	.154
St.Louis-San Francisco	6 743.73	3 139	1 363 317	202	0.98	198	6.4	2 634 412	.075
St.Louis,San Francisco & Texas	252.83	3 168	108 034	427	0.90	385	13.5	1 165 941	.330
St.Louis Southwestern Lines	2 011.53	3 167	145 300	72	1.19	86	2.3	2 964 053	.029
Texas & New Orleans	5 766.58	2 718	697 958	121	0.70	85	4.5	2 466 471	.034
Texas & Pacific	2 529.57	2 947	198 166	78	0.82	64	2.7	3 926 826	.016
Texas Mexican	205.65	2 880	31 345	152	1.06	161	5.3	1 051 196	.154
Wichita Falls & Southern	196.62	3 300	33 762	172	0.83	142	5.2	572 590	.249
CANADIAN ROADS:									
Canadian National	30 221.00	2 865	5 977 704	198	0.95	188	6.9	2 039 387	.092
Canadian Pacific	21 788.00	2 838	3 621 334	166	0.81	135	5.9	2 235 559	.060
Temiskaming & Nor.Ontario	637.21	2 847	156 159	245	0.69	170	8.6	1 502 989	.113

Col.3 derived by dividing Col.9 Table A by Col.8 of same table.
Col.4 is total of column 2 and 4 of Table A.
Col.5 derived by dividing the totals of columns 2 and 4 of Table A, by Col.8 of same table.
Col.6 is weighted average of costs shown in columns 3 and 5 of Table A.
NOTE: Compiled from Annual Reports of Class I Steam Roads to the Interstate Commerce Commission.

TABLE

NUMBER AND AGGREGATE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK A

Class I roads in the United States and large Canadian roads, by yea

Note: All figures are exclusive

Road	Number of wooden cross tie renewals per mile of maintained track	A

Sheet 1 of 2 sheets

TABLE 3

NUMBER AND AGGREGATE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF WOODEN CROSS TIE RENEWALS TO TOTAL WOODEN CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1930 to 1934 inclusive

Note: All figures are exclusive of bridge and switch ties.

Road	Number of wooden cross tie renewals per mile of maintained track						Aggregate cost of wooden cross tie renewals per mile of maintained track						Per cent wooden cross tie renewals to all ties in tracks					
	1930	1931	1932	1933	1934	5 year average	1930	1931	1932	1933	1934	5 year average	1930	1931	1932	1933	1934	5 year average
NGLAND REGION:																		
gor & Aroostook	253	236	203	189	204	217	$207	$183	$160	$126	$127	$161	8.8	8.2	7.1	6.6	7.1	7.6
ton & Maine	236	164	64	75	118	131	385	271	99	118	198	214	8.7	5.4	2.2	2.6	4.1	4.6
adian National Lines in N.E.	160	87	57	87	85	95	251	129	72	122	114	138	5.0	2.8	1.9	2.8	2.8	3.1
adian Pacific (lines in Me.)	320	262	181	170	182	223	397	362	270	242	252	305	11.1	9.1	6.3	5.9	6.3	7.7
adian Pacific (lines in Vt.)	313	254	200	134	68	194	413	362	297	192	98	272	10.0	7.5	5.8	3.9	2.0	5.8
tral Vermont	244	237	174	184	193	206	427	421	315	292	261	343	7.6	7.5	5.5	6.0	6.3	6.6
ne Central	244	222	184	167	192	202	273	257	212	162	216	224	8.0	7.3	6.1	5.5	6.3	6.6
York Connecting	194	293	229	131	257	221	382	580	434	238	411	409	6.1	9.3	7.2	4.1	8.0	6.9
York,New Haven & Hartford	253	165	121	73	62	135	412	277	187	108	85	214	8.2	5.8	4.2	2.5	2.2	4.6
land	224	210	189	147	129	180	305	337	270	174	134	256	7.5	7.0	6.3	4.9	4.3	6.0
LAKES REGION:																		
Arbor	148	114	179	130	106	135	226	175	264	193	141	200	4.9	3.8	6.0	4.3	3.6	4.5
ria & Indiana	a	a	235	348	341	308	a	a	273	312	296	294	a	a	8.6	12.7	12.4	11.2
aware & Hudson	172	111	125	139	103	130	432	266	289	297	206	298	5.7	3.6	4.1	4.6	3.4	4.3
aware,Lackawanna & Western	80	76	64	53	108	76	151	141	108	72	128	120	2.8	2.6	2.2	1.8	3.7	2.6
roit & Mackinac	202	97	126	114	101	128	194	107	95	79	58	107	6.7	5.2	4.2	3.8	3.4	4.3
roit & Toledo Shore Line	112	84	88	100	83	93	235	177	145	166	137	172	3.6	2.7	2.9	3.3	2.7	3.0
e (Inc.Chgo.& Erie)	199	173	135	106	104	143	422	341	248	154	144	262	7.0	6.1	4.7	3.7	3.6	5.0
nd Trunk Western	191	156	115	141	152	151	252	210	155	179	190	197	5.9	4.6	3.6	4.5	4.8	4.7
igh & Hudson River	66	54	55	22	23	44	127	100	81	38	40	77	2.5	2.1	2.1	0.9	0.9	1.7
igh & New England	121	107	72	72	75	89	243	207	141	132	127	170	4.1	3.6	2.4	2.4	2.5	3.0
igh Valley	64	53	45	63	66	58	118	97	83	92	94	97	2.2	1.8	1.7	2.1	2.2	2.0
ongahela	215	145	81	131	155	145	368	228	121	221	278	243	7.6	5.0	2.8	4.5	5.4	5.1
tour	259	163	95	102	115	147	552	302	165	159	218	279	9.2	5.6	3.4	3.6	4.1	5.2
Jersey & New York	167	145	172	111	82	135	319	260	293	152	100	225	5.8	5.0	6.0	3.8	2.8	4.7
York Central R.R.Co.(see note)	111	91	52	52	70	75	207	163	87	82	102	128	3.8	3.1	1.7	1.7	2.5	2.6
York,Chicago & St.Louis	135	70	73	61	84	85	254	132	133	114	151	157	4.2	2.3	2.4	2.0	2.1	2.7
York,Ontario & Western	119	116	105	90	69	100	206	196	163	107	82	151	4.2	4.1	3.7	4.2	2.4	3.5
York,Susquehanna & Western	174	125	112	113	130	131	322	204	164	151	170	202	6.0	4.3	3.9	3.9	4.5	4.5
e Marquette	168	191	140	118	123	148	294	319	213	149	164	228	6.4	6.3	4.7	3.9	4.1	5.1
tsburgh & Lake Erie	62	4	5	35	41	29	151	7	10	75	76	64	2.1	0.1	0.2	1.2	1.4	1.0
tsburg & Shawmut	158	159	182	218	260	195	188	136	134	184	241	177	5.7	5.7	6.5	7.9	9.3	7.0
sburgh & West Virginia	108	117	88	114	187	123	176	151	114	96	186	145	3.7	4.0	3.0	3.9	6.5	4.2
sburg,Shawmut & Northern	185	165	140	154	183	165	333	210	159	163	249	223	6.4	5.7	4.8	5.3	6.3	5.7
sh	177	119	134	129	130	138	253	145	205	203	190	199	5.6	3.8	4.3	4.1	4.2	4.4
L EASTERN REGION:																		
n,Canton & Youngstown	250	115	155	171	264	191	445	212	202	186	333	276	8.7	4.0	5.4	6.0	9.2	6.7
more & Ohio (see note)	123	51	47	73	81	75	205	82	79	117	132	123	4.4	1.8	1.7	2.6	2.9	2.7
emer & Lake Erie	231	238	171	151	241	206	508	465	315	264	501	411	7.3	7.6	5.5	4.8	7.8	6.6
ral R.R.of New Jersey	83	82	72	45	33	63	156	151	131	77	54	114	2.9	2.9	2.6	1.6	1.2	2.2
ago & Eastern Illinois	101	98	100	92	98	98	152	145	144	96	109	129	3.2	3.2	3.2	3.0	3.2	3.2
ago & Illinois Midland	126	105	112	107	64	103	202	148	115	114	80	132	4.2	3.5	3.6	3.5	2.1	3.4
ago,Indianapolis & Louisville	156	99	66	65	82	94	207	128	84	74	83	115	5.1	3.2	2.2	2.1	2.6	3.0
oit,Toledo & Ironton	149	71	90	92	142	109	244	117	155	126	172	163	5.2	2.5	3.1	3.2	4.9	3.8
n,Joliet & Eastern	226	165	96	124	165	155	353	248	137	155	227	224	7.3	5.3	3.1	4.0	5.3	5.0
nois Terminal	94	84	83	90	73	85	130	105	103	87	68	99	3.5	3.1	3.1	3.2	2.7	3.1
Island	129	91	69	42	64	79	241	167	120	64	103	139	4.6	3.2	2.7	1.4	2.2	2.8
uri-Illinois	197	221	138	183	296	207	[illegible]	153	58	83	168	133	6.4	7.1	4.4	5.9	9.6	6.7
sylvania R.R.,see note)	124	75	48	58	64	74	227	138	81	97	100	129	4.4	2.7	1.7	2.1	2.3	2.6
a.-Reading Seashore Lines (see note)	109	114	23	4	56	61	230	230	42	9	75	117	3.9	4.0	0.8	0.2	2.1	2.2
ing Company	137	105	28	29	35	67	247	188	47	48	60	118	4.8	3.8	1.0	1.1	1.3	2.4
en Island Rapid Transit	73	62	54	64	69	64	147	128	131	170	175	150	2.6	2.3	1.9	2.3	2.5	2.3
ern Maryland	206	187	116	180	219	182	274	238	185	244	260	240	7.1	6.5	4.0	6.2	7.6	6.3
ling & Lake Erie	171	133	46	78	63	98	258	203	67	113	85	145	5.7	4.4	1.5	2.6	2.1	3.3
NTAS REGION:																		
apeake & Ohio	173	127	84	92	94	114	239	157	102	105	104	141	5.6	4.1	2.7	3.0	3.1	3.7
olk & Western	176	164	114	106	90	130	248	214	136	123	102	165	5.7	5.3	3.7	3.4	2.9	4.2
mond,Fred'burg & Potomac	401	295	298	298	344	327	457	286	236	215	260	291	14.0	10.3	10.4	10.4	12.0	11.4
inian	342	234	169	205	208	232	373	249	193	225	221	252	10.9	7.4	5.4	6.6	6.7	7.4
RN REGION:																		
ama Great Southern	342	343	235	213	275	282	469	491	317	255	335	373	11.1	11.1	7.6	6.9	8.9	9.1
nta & West Point	198	160	108	176	151	159	255	228	154	256	225	224	7.5	6.1	3.6	5.8	5.0	5.6
stern Ry.of Alabama	268	171	67	168	120	159	346	244	93	235	173	218	8.9	6.5	2.2	5.6	4.0	5.4
nta,Birmingham & Coast	243	222	179	126	151	184	277	253	151	70	110	172	8.4	7.7	6.2	4.4	5.2	6.4
ntic Coast Line	218	210	186	152	145	182	238	214	157	91	114	163	7.5	7.2	6.4	5.2	5.0	6.3
ral of Georgia	144	143	109	116	121	127	131	120	84	79	85	100	5.2	5.1	3.9	4.2	4.3	4.5
leston & Western Carolina	275	237	205	197	163	215	327	256	197	157	159	219	9.9	8.6	7.0	6.7	5.6	7.6
innati,New Orleans & Tex.Pac.	300	281	185	157	163	217	447	432	271	219	235	321	9.7	9.1	5.9	5.0	5.2	7.0
chfield	477	399	376	372	314	388	425	394	375	309	272	355	15.7	13.1	12.4	12.2	10.3	12.7
mbus & Greenville	415	152	229	219	220	247	519	171	247	176	198	262	13.1	4.8	7.2	6.9	6.9	7.8
ida East Coast	36	34	93	172	135	94	40	32	51	87	102	62	1.2	1.2	3.2	6.0	4.7	3.3
gia R.R.	250	240	178	194	133	199	335	326	230	214	143	250	8.3	8.1	5.8	6.3	4.3	6.6
gia & Florida	216	256	155	201	266	219	157	163	87	95	136	126	8.0	9.5	5.8	7.5	9.8	8.1
gia,Southern & Florida	247	256	153	83	99	168	259	263	144	54	69	158	7.9	8.2	4.9	2.7	3.2	5.4
& Ship Island	320	288	30	135	171	189	352	292	26	67	78	163	10.4	9.3	1.0	4.4	5.6	6.1
Mobile & Northern (see note)	220	142	136	119	157	155	223	148	109	81	120	136	6.9	4.4	4.4	4.0	5.0	4.9
nois Central	161	166	79	95	135	127	187	190	86	91	122	135	5.3	5.4	2.6	3.1	4.4	4.2
oo & Miss.Valley	237	236	70	93	123	152	294	285	78	84	102	169	7.6	7.7	2.3	3.0	4.0	4.9
ville & Nashville	200	168	103	109	110	138	314	273	167	147	134	207	7.2	5.8	3.6	3.8	3.8	4.8
ssippi Central	204	167	96	106	155	146	237	171	89	101	148	149	6.5	5.3	3.0	3.4	4.9	4.6
e & Ohio	361	287	272	230	317	293	318	204	154	131	214	204	11.4	9.1	8.6	7.1	10.0	9.2
ille,Chattanooga & St.Louis	296	319	243	229	173	252	403	412	282	236	173	301	10.0	10.8	8.2	7.7	5.9	8.5
rleans & Northeastern	273	248	222	185	196	225	349	354	276	162	224	273	8.9	8.0	7.2	6.0	6.3	7.3
lk Southern	306	228	163	284	386	273	269	169	99	150	224	182	10.8	8.0	5.7	10.0	13.6	9.6
ern Alabama	385	351	325	375	364	360	381	301	248	257	301	298	12.2	11.1	10.3	11.9	11.5	11.4
ard Air Line	227	258	215	204	215	224	227	238	161	135	171	186	7.3	8.3	6.9	6.6	7.7	7.4
ern Ry.	351	336	298	260	282	305	386	358	296	200	273	303	11.1	10.6	9.4	8.2	9.0	9.7
ssee Central	310	258	246	415	325	311	341	333	277	265	242	292	10.0	8.2	7.9	13.2	10.4	9.9

TABLE C

NUMBER AND AGGREGATE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AN

Class I roads in the United States and large Canadian roads, by year

Note: All figures are exclusive

Road	Number of wooden cross tie renewals per mile of maintained track						Ag
	1930	1931	1932	1933	1934	5 year average	193

TABLE 2

UMBER AND AGGREGATE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF WOODEN CROSS TIE RENEWALS TO TOTAL WOODEN CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1930 to 1934 inclusive

Note: All figures are exclusive of bridge and switch ties.

Road	Number of wooden cross tie renewals per mile of maintained track						Aggregate cost of wooden cross tie renewals per mile of maintained track						Per cent wooden cross tie renewals to all ties in track					
	1930	1931	1932	1933	1934	5 year average	1930	1931	1932	1933	1934	5 year average	1930	1931	1932	1933	1934	5 year average
ESTERN REGION:																		
ago & North Western	173	136	108	100	116	127	$202	$162	$123	$100	$111	$140	[illegible]	4.7	3.7	3.4	[illegible]	4.3
ago Great Western	220	243	247	179	194	217	255	[illegible]	[illegible]	179	209	[illegible]	[illegible]	[illegible]	5.5	6.1	[illegible]	[illegible]
ago,Milwaukee,St.Paul & Pacific	214	185	162	133	184	176	231	205	167	131	168	[illegible]	7.4	6.4	[illegible]	4.5	[illegible]	6.0
ago,St.Paul,Minpls.& Omaha	223	255	201	152	164	199	[illegible]	267	229	[illegible]	[illegible]	[illegible]	7.5	[illegible]	6.3	[illegible]	[illegible]	[illegible]
tr,Missabe & Northern (see note)	174	160	11	38	62	89	289	257	14	53	92	141	5.5	[illegible]	[illegible]	1.3	2.1	[illegible]
tr,South Shore & Atlantic	235	214	157	155	161	184	179	148	54	70	54	113	7.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
tr,Winnipeg & Pacific	266	321	246	270	375	296	[illegible]	240	167	137	177	[illegible]	8.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Northern	190	168	140	40	110	130	224	[illegible]	158	87	125	141	[illegible]	[illegible]	4.4	[illegible]	[illegible]	4.1
er Bay & Western	296	300	268	328	340	306	255	245	189	199	212	[illegible]	[illegible]	[illegible]	[illegible]	11.7	[illegible]	10.9
Superior & Ishpeming	230	150	105	148	186	164	166	117	76	100	102	112	7.7	[illegible]	[illegible]	[illegible]	6.2	5.5
eapolis & St.Louis	122	102	101	88	104	103	139	112	111	81	95	[illegible]	[illegible]	[illegible]	[illegible]	2.4	[illegible]	3.4
eapolis,St.Paul & S.S.Marie	222	173	164	169	158	177	271	193	173	143	130	182	7.5	[illegible]	[illegible]	5.6	5.4	6.1
ern Pacific	124	103	101	97	82	101	156	127	122	105	89	120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.5
n-Washington R.R.& Nav Co.	167	98	65	84	119	107	164	99	65	85	114	[illegible]	5.7	3.4	[illegible]	2.9	4.1	3.7
ane International	348	326	367	263	313	323	195	175	182	112	137	160	[illegible]	11.5	[illegible]	[illegible]	11.1	11.5
ane,Portland & Seattle	294	216	174	154	142	196	385	239	140	72	68	161	[illegible]	7.2	5.8	5.1	4.7	6.6
L WESTERN REGION:																		
n R.R.	254	241	213	203	263	235	284	243	212	202	293	247	9.0	[illegible]	7.1	[illegible]	[illegible]	7.9
ison,Topeka & Santa Fe (see note)	162	111	78	77	97	105	219	146	98	92	105	132	5.3	[illegible]	2.5	2.5	[illegible]	3.4
ago,Burlington & Quincy	151	134	106	64	91	109	195	170	133	78	109	137	[illegible]	[illegible]	3.4	[illegible]	2.9	3.5
ago,Rock Island & Pacific	128	106	38	46	61	76	141	116	42	51	63	83	[illegible]	3.5	[illegible]	1.5	[illegible]	2.5
icago,Rock Island & Gulf	185	98	44	55	70	90	296	161	74	96	112	148	6.1	[illegible]	1.5	1.7	2.2	3.0
rado & Southern	140	116	112	110	144	124	153	122	98	77	123	115	4.6	3.8	[illegible]	[illegible]	4.7	4.1
ver & Rio Grande Western	175	162	130	129	167	153	[illegible]	190	141	126	168	167	5.6	[illegible]	[illegible]	[illegible]	5.4	4.9
ver & Salt Lake	138	130	123	201	193	157	168	160	125	159	[illegible]	155	4.6	[illegible]	4.1	[illegible]	[illegible]	[illegible]
Worth & Denver City	178	90	68	31	33	80	240	118	88	37	36	104	[illegible]	[illegible]	[illegible]	1.0	1.1	2.6
Angeles & Salt Lake	132	124	112	137	166	134	215	202	182	233	215	209	[illegible]	4.5	4.0	4.9	5.9	4.8
da Northern	169	133	134	117	129	136	162	117	103	83	96	112	5.9	4.6	[illegible]	4.1	[illegible]	4.8
hwestern Pacific	270	210	106	76	136	160	205	153	66	38	73	107	9.2	7.1	3.6	2.6	4.6	5.4
on Short Line	151	111	59	75	108	101	198	147	78	100	126	130	5.4	[illegible]	2.1	2.7	3.9	3.6
oseph & Grand Island	126	124	69	97	165	116	169	152	86	167	291	173	[illegible]	4.2	2.3	3.3	5.6	3.9
Diego & Arizona Eastern	132	90	84	113	146	113	160	103	80	100	115	112	4.5	3.1	2.9	3.8	5.0	3.9
thern Pacific Co.- Pac.Lines	164	137	97	57	65	104	198	164	105	56	66	118	5.6	4.7	3.3	1.9	2.2	3.5
do,Peoria & Western	155	166	155	212	256	189	189	179	137	210	309	205	4.5	5.2	4.9	6.7	8.1	6.0
n Pacific	123	108	85	86	126	106	169	147	118	116	161	142	[illegible]	3.8	3.0	3.1	4.5	3.7
Ry.	234	187	110	94	166	158	321	244	128	118	194	201	9.0	7.2	4.2	3.6	6.4	6.1
ern Pacific	338	261	199	277	274	270	281	211	127	163	172	191	11.6	8.9	6.8	9.5	9.4	9.2
ESTERN REGION.																		
ington-Rock Island	400	145	22	27	56	130	328	144	22	17	38	110	12.8	4.6	0.7	0.9	1.8	4.2
Smith & Western	311	241	254	203	287	259	202	87	110	93	143	127	9.9	7.7	8.1	6.6	9.2	8.3
Worth & Rio Grande	153	118	156	228	144	160	207	154	195	188	118	172	4.8	3.7	4.9	7.2	4.6	5.0
Coast Lines:																		
eaumont,Sour Lake & Western	216	115	58	76	110	115	281	147	66	83	109	137	7.3	3.9	2.0	2.5	3.7	3.9
w Orleans,Texas & Mexico	224	126	93	113	104	132	293	161	105	124	105	158	7.3	4.1	3.0	3.7	3.4	4.3
.Louis,Brownsville & Mexico	158	60	28	30	45	64	172	65	29	30	41	67	5.2	2.0	0.9	1.0	1.5	2.1
n Antonio,Uvalde & Gulf	240	225	132	94	77	154	307	288	158	108	76	187	8.3	7.8	4.6	3.3	2.7	5.3
rnational-Great Northern	204	167	93	123	112	140	235	190	91	112	96	145	6.8	5.6	3.1	4.1	3.7	4.7
as City Southern (see note)	165	147	143	121	109	137	210	166	152	122	99	148	5.3	4.7	4.6	3.8	3.4	4.4
, Oklahoma & Gulf	117	107	92	137	[illegible]	[illegible]	[illegible]	123	93	133	193	141	3.7	[illegible]	2.9	[illegible]	[illegible]	[illegible]
siana & Arkansas	339	253	164	251	251	256	[illegible]	224	146	167	157	[illegible]	10.7	[illegible]	[illegible]	[illegible]	7.9	[illegible]
siana,Arkansas & Texas	374	309	242	416	354	339	344	324	173	165	164	234	[illegible]	9.7	7.6	[illegible]	11.7	[illegible]
and Valley	165	112	76	94	97	109	224	128	80	98	96	125	5.1	3.5	2.4	[illegible]	3.0	3.4
ouri & North Arkansas	250	240	178	216	327	242	175	124	77	90	154	124	8.0	8.1	5.7	7.6	[illegible]	7.9
ouri-Kansas-Texas Lines	162	93	120	99	127	120	214	94	93	108	138	129	5.1	3.0	3.8	3.1	4.0	3.8
ouri Pacific	217	164	96	164	169	162	232	166	99	142	150	162	7.0	5.3	3.1	5.3	5.4	5.2
homa City-Ada-Atoka	404	108	97	42	119	154	347	69	61	29	82	118	12.9	3.6	3.1	1.3	3.8	[illegible]
ouis-San Francisco	168	124	167	204	202	173	190	137	166	188	198	176	5.4	4.0	5.4	6.5	6.4	5.5
ouis,San Fran.& Texas	149	133	164	278	427	230	194	170	191	229	385	234	4.7	4.2	5.2	8.6	13.5	7.3
ouis Southwestern Lines	207	92	78	57	72	101	251	112	94	67	86	122	6.5	2.9	2.5	1.8	2.3	3.2
s & New Orleans	173	139	99	87	121	124	223	176	112	77	85	135	6.3	5.1	3.7	3.2	4.5	4.6
s & Pacific	170	107	54	69	78	96	194	128	57	66	64	102	5.4	3.6	1.8	2.4	2.7	3.2
s Mexican	[illegible]	184	152	124	152	176	379	218	159	123	161	208	9.4	6.4	5.3	4.3	5.3	6.1
ita Falls & Southern	247	224	176	158	172	195	314	245	174	149	142	205	7.5	6.8	5.3	4.8	5.2	5.9
AN ROADS:																		
dian National (see note)	220	210	162	164	198	186	327	297	180	138	188	168	7.9	7.3	5.6	5.7	6.9	6.5
dian Pacific (see note)				161	166	184				164	135	220				5.6	5.9	6.5
skaming & Nor.Ontario				216	245	235				154	170	175				7.5	8.6	8.1

NOTE: Statement applies to Class I roads and includes consolidated data for Class I roads merged during the period 1930 to 1934, as follows:
Baltimore & Ohio - includes Buffalo,Rochester & Pittsburgh and Buffalo & Susquehanna.
New York Central - includes Evansville,Indpls.& Terre Haute; Cincinnati Northern; Cleveland,Cincinnati,Chicago & St.Louis; Michigan Central, and Ulster & Delaware.
Pennsylvania - includes West Jersey & Seashore up to and including 1932.
Penna.-Reading Seashore Lines - includes Atlantic City and West Jersey & Seashore; organized as Class I road in 1933. Figures shown are for Atlantic City R.R. only, 1930-1932 inclusive.
Gulf,Mobile & Northern - includes New Orleans Great Northern.
Duluth,Missabe & Northern - includes Duluth & Iron Range.
Atchison,Topeka & Santa Fe - includes Panhandle & Santa Fe and Gulf,Colorado & Santa Fe.
Canadian National Rys. - includes lines in New England, Grand Trunk Western, and Duluth,Winnipeg & Pacific.
Canadian Pacific - includes all lines.
Kansas City Southern - includes Texarkana & Fort Smith.

a Not a Class I road prior to 1932.

Appendix C

(9) SPECIFICATIONS FOR PRE-ADZING AND PRE-BORING CROSS-TIES

R. S. Belcher, Chairman, Sub-Committee; H. F. Brown, R. E. Butler, E. E. Chapman, H. R. Clarke, C. F. Ford, C. S. Kirkpatrick, L. O. Lower, Sverre Thorvaldson.

The preservative treatment of cross-ties in large quantities at single locations provided opportunity for the mass machining of them. Equipment for planing areas on which plates would sit evenly was first designed. It was soon expanded by the addition of bits to bore holes which would receive spikes with minimum damage to the wood fibers. Subsequently, saws to trim ties to exact lengths, and hammers to brand their ends were added. Recently, gouges to make grooves for accommodating the bottom ribs of plates have been installed. And to permit the penetration of preservative into woods which are resistive to treatment, machines with teeth to puncture the surfaces of ties and timbers have been devised.

In order that standard requirements may be available for all the kinds of preparation for ties which are being practiced, the Committee has enlarged the field of its assignment beyond adzing and boring, and submits for adoption and inclusion in the Manual the following comprehensive specifications.

SPECIFICATIONS FOR MACHINING CROSS-TIES—1936

When so ordered, ties shall be adzed, grooved, bored, trimmed, incised, and/or branded in accordance with the following specifications, carried out subsequent to seasoning and immediately prior to preserving:

Adzing

1.1 Adzing shall be on the top of the tie across its full width to a depth not greater than necessary for a full, smooth and true bearing under the tie plates, except in the case of a bowed, checked or split tie which must be used with the top down and consequently adzed on the bottom.

1.2 The adzed surfaces shall be in the same plane at both ends of the tie, and shall be so flat that a straight edge laid across them shall not be more than 1/16-inch from the adzed surface at any point.

1.3 The location and length of the adzing shall conform to plans provided, and permitting a tolerance of ¼-inch in the location of the adzed area with respect to the spike holes.

1.4 Spurs on adz heads shall be set to the same depth as the knives, or to not exceed 1/16-inch deeper.

1.5 Adz knives and spurs shall be sharp and the whole equipment kept in such condition that adzing will be properly done.

Grooving

2. Grooving shall conform to plans provided, and the location of the grooves with respect to the spike holes shall be within the tolerances permitted for spike holes.

Boring

3.1 Boring for spike holes shall conform in size* and location to plans provided, with plus or minus 1/16-inch permitted in each distance between holes. The spike holes shall be centered across the width of the tie in such a way that the tie plates will center on the tie when the spikes are driven into the pre-bored holes. A tolerance of ⅛-inch in the centering of the holes across the width of the tie is permissible.

---

* See Manual (page 134) for recommended sizes of holes.

3.2 Spike holes shall be bored entirely through the tie from top to bottom, except in the case of ties for use in direct-current electric lines having covered track.

3.3 When the head diameter of the bits has been reduced 1/16-inch by wear, bits shall be replaced. Cutting heads of bits shall be sharpened at regular intervals to insure clean boring.

Incising

4. Incising shall be on four sides of the ties for a depth of ¾-inch with teeth not more than 5/32-inch thick, to the pattern shown in Fig. 1, Supplement to the Manual, page 122, Vol. 36, 367–368.

Trimming

5.1 Trimmed ties shall be cleanly sawed at both ends to the specified length as they pass through the boring and adzing machine.

5.2 Machines shall be preferably equipped with devices for centering the ties lengthwise and where machines are so equipped equalizers and guides shall be so set that an equal amount is cut from each end of the tie. When machines are not equipped with equalizers, guides shall be set to trim ½-inch from one (line) end of tie and sufficient from the opposite end to result in the specified length.

Branding

6.1 Branding of ends of ties as they pass through the machine shall be with letters, figures, or symbols to indicate one or more of the following:

Wood,
Treatment,
Weight of rail for which bored,
Year,
Size,
Identity of Plant,
Identity of Railroad.

6.2 The height of letters and figures shall be 1.5-inch. Dies used for branding shall have cutting edges ⅛-inch wide which shall indent the wood at least ¼-inch deep.

REPORT OF COMMITTEE IV—RAIL

Earl Stimson, *Chairman;*
John E. Armstrong,
W. J. Backes,
J. B. Baker,
W. C. Barnes,
F. L. C. Bond,
N. J. Boughton,
C. B. Bronson,
E. E. Chapman,
C. T. Dike,
W. A. Duff,
Robert Faries,
J. M. Farrin,
L. C. Fritch,
F. W. Gardiner,
F. M. Graham,
G. T. Hand,
C. R. Harding,
G. W. Harris,
B. Herman,
F. S. Hewes,
C. W. Johns,
W. H. Kirkbride,
H. C. Mann,
Wm. Michel,
A. A. Miller,
John V. Neubert,
E. E. Oviatt,
J. C. Patterson,
W. H. Penfield,
A. F. Blaess, *Vice-Chairman;*
W. H. Petersen,
G. A. Phillips,
G. J. Ray,
A. N. Reece,
R. T. Scholes,
G. R. Smiley,
C. P. Van Gundy,
J. C. Wallace,
C. E. Weaver,
J. E. Willoughby,
W. P. Wiltsee,
Louis Yager,
J. B. Young,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual (Appendix A).

(2) Further research, including details of mill practice and manufacture as they affect rail quality and rail failures, giving special attention to transverse fissure failures, collaborating with Rail Manufacturer's Technical Committee (Appendix B). Progress report.

(3) Compilation of statistics of all rail failures, making special study of transverse fissure failures (Appendices C, D and E). Progress reports.

(4) Cause and prevention of rail battering and methods of reconditioning rail ends, fastenings, and frogs in track (Appendix F).

(5) Economic value of different sizes of rail. No report.

(6) Rail lengths in excess of 39 feet (Appendix G). Progress report.

(7) Cause of the corrugation of rails, collaborating with Mechanical Division (Appendix H).

(8) Service tests of various types of joint bars. No report.

(9) Effect of different kinds of ballast on life of rail and upon rail failures. No report.

(Special) Design joint bars for 90-lb. RA–A and 100-lb. RE rail sections (Appendix I).

The Committee on Rail,
Earl Stimson, *Chairman.*

Bulletin 383, January, 1936.

Appendix A

(1) REVISION OF MANUAL

A. F. Blaess, Chairman, Sub-Committee; John E. Armstrong, W. C. Barnes, N. J. Boughton, C. B. Bronson, E. E. Chapman, W. A. Duff, L. C. Fritch, F. M. Graham, C. R. Harding, G. W. Harris, C. P. Van Gundy, C. E. Weaver, J. B. Young.

Your Committee has thoroughly reviewed the Manual, also the several Supplements, and has found considerable material which in its opinion can be improved in wording, simplified, or made more definite in meaning and for these reasons recommends the following changes:

Definitions, including title: To be revised and rearranged as follows:

DEFINITIONS—RAIL AND FASTENINGS

Materials

Commercial Iron.—The element iron as pure as it is commercially produced.

Pig Iron.—The product, either cast or in a molten state, resulting from heating iron ore, limestone and coke together in a blast furnace, after removal of the molten impurities as slag.

Pig iron contains a high percentage of carbon ranging from 3.0 to 4.0 per cent.

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron, with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Steel.—A ferrous material produced in a fluid condition, usually by the Bessemer, open-hearth or electric furnace process. It is practically free from slag, distinguishing it from wrought iron, and in general contains less than 1.50 per cent of carbon, distinguishing it from cast iron.

Carbon Steel (or Plain Steel).—Steel containing only the elements carbon, manganese, phosphorus, sulphur and silicon in addition to iron, the properties of which are due essentially to the presence of carbon.

Alloy Steel.—Steel containing one or more elements in addition to carbon in a sufficient proportion to modify or improve substantially and positively some of its useful properties.

Alloy steels, since they contain one or more special elements, are sometimes called special steels.

Manufacture

Bessemer Process.—The conversion of liquid pig iron to steel by forcing air at atmospheric temperature through it in a furnace in which no extraneous fuel is burned, resulting in the oxidation or reduction of the carbon, manganese and silicon to the extent desired and their removal in the form of slag. As more carbon and manganese are removed than finally required, the proper addition of these elements must be made to the metal on completion of the blow.

Acid Bessemer.—Steel made by the Bessemer process in a furnace having an acid lining, usually ganister or other highly siliceous material. Phosphorus and sulphur are not removed in the refining process.

Basic Bessemer.—Steel made by the Bessemer process in a furnace having a basic lining, usually either magnesite or burned dolomite. Phosphorus is oxidized and removed in the basic slag but the removal of sulphur is uncertain.

Bessemer Converter.—A tilting furnace lined with acid or basic material in which molten pig iron is converted to steel by the Bessemer process.

Open-Hearth Process.—The conversion of solid pig iron with the addition of iron or steel scrap to steel through exposure to burning gases in a reverberatory furnace. In the refining of the molten metal, the carbon is generally reduced considerably below the percentage ultimately required and the metal is thereafter recarburized. Usually additions of manganese and silicon are also made.

Acid Open-Hearth.—Steel made by the open-hearth process in a furnace lined with acid or siliceous material. This process demands special selection of pig iron and scrap, as phosphorus and sulphur are not removed in refining on a silica bed.

Basic Open-Hearth.—Steel made by the open hearth process in a furnace lined with basic material, usually either magnesite or burned dolomite. Limestone is added to the pig iron and scrap in the furnace as an aid in removing phosphorus. The slag is basic. The removal of phosphorus, and of sulphur to a lesser degree, being under control, a lower grade of pig iron and scrap may be used than in the Acid Open-Hearth process.

Open-Hearth Furnace.—A rectangular furnace built of brick, lined with acid or basic materials and having a hearth on which metal may be openly exposed to the action of burning gases.

Electric Furnace Process.—The process of making steel from steel scrap or from steel scrap and iron ore with limestone as a flux in a furnace, usually of the rocking or tilting type, built of steel plates and lined with fire-brick or other refractory materials, in which the source of heat is a low voltage electric current of high amperage. The furnace lining may be either acid or basic.

Annealing.—The process of raising and holding the temperature of a steel product above its critical temperature range for a time, followed by slow cooling, for the purpose of equalizing internal stresses and increasing ductility and toughness.

Blow.—The period during which air is forced through the molten metal in the Bessemer process, or the action itself, or the steel produced from one charge.

Charge.—The molten pig iron placed in a Bessemer converter, or the solid pig iron, steel scrap, limestone and other materials placed in the open-hearth furnace for conversion into steel.

Cinder Heat.—The heating of a bloom or ingot in a heating furnace to such a degree that a certain amount of oxide or scale formed on the outer surface of the piece, melts and runs off.

Critical Temperatures.—Temperatures at which, during heating or cooling, marked internal crystalline or molecular transformations occur in iron or steel, resulting in the absorption or evolution of heat and alterations in the physical properties of the material.

Deoxidized Steel.—Steel from which oxygen and other gases have been removed, so far as practical, during manufacture to prevent the formation of blow holes in the ingot. The principal deoxidizers are manganese, silicon, titanium and aluminum.

Heat or Melt.—The steel resulting from one charge.

Ingot.—A special form of casting poured direct from the teeming ladle for subsequent rolling or forging.

* Hot Top or Sinkhead Ingot.—Bulletin 327, page 10.

Bled Ingot.—An ingot which has fallen over while solidifying, or has met with some other mishap, allowing the liquid interior to escape but leaving the walls intact. It may bleed at the top or at the bottom, but usually at the top.

Butt Ingot.—A short ingot, usually the last one poured from a heat, for which there is not sufficient steel to fill the mold. The lower end of an ingot is sometimes called the butt of the ingot.

Ingot Stool.—The plate or base on which an open bottom ingot mold stands.

Piping.—Manual, page 137.

Segregation.—Positive—The concentration of the carbon and impurities (in solution) in that part of an ingot or other casting which solidifies last.

Negative.—The condition existing where any part of the ingot or casting has less than the average amount of carbon and impurities.

Soaking Pit.—A heated pit in which the ingot, after being stripped, is placed for the purpose of equalizing the temperature throughout its mass.

Tapping.—The removal of the molten steel from the open-hearth furnace by opening the tap hole and allowing the metal to run into the ladle.

Teeming.—The pouring of the metal from the ladle into the ingot molds.

Rolling Mill Practice

Billet.—A bar of iron or steel of square or rectangular cross-section, approximately the size and length required for the finished article to be produced from it; a small bloom.

Note.—In definitions giving reference to Manual or Bulletins, no change has been made in the wording.

BLOOM.—An intermediate product resulting from the rolling of an ingot. In rail making it is usually about eight inches square, but may be rectangular in cross-section.

REHEATING OF BLOOMS.—The heating of blooms, after leaving the bloom shears, in a furnace to secure proper temperatures for rolling.

BURRS.—The rough edges left at the end of a rail when sawed hot; or on the side of the web when drilling bolt holes.

CAMBERING MACHINE.—A machine for giving hot rails as they come from the rolls the curvature necessary to compensate for the unequal cooling of head and base, so they will be as nearly straight as possible when cold.

COBBLE.—Any piece of steel bent or twisted to such an extent it cannot be finished by rolling.

CROP END.—Bulletin 367–8, page 15.

CROPPING.—Manual, page 137.

GAGGING.—The work done on the rail at the straightening press with a steel "gag" or tool for the purpose of taking out a bend.

HOTBED.—A series of skids on which rails are placed for cooling after rolling, sawing and cambering.

LUMPY.—Manual, page 137.

MILLING RAIL.—The cutting of the ends of the rails with a milling hob to eliminate roughness and inaccuracies of sawing.

PASS.—The passage of any piece of metal through the rolls of a rolling mill as an ingot through the blooming rolls; or the openings in the various rolls or roll trains, which give the hot metal the desired shape.

RAIL SECTION.—The shape of the end of a rail cut at right angles to its length.

SHRINKAGE ALLOWANCE.—The excess length to which a hot rail is cut when leaving the rolls to allow for shrinkage to required length when cold.

TEMPLET.—Usually a piece of thin metal of the exact size and shape of the finished rail section, but it may be of the size and shape of the rail section when hot, or the reverse of the shape to be fitted over a hot or cold rail to check its shape.

FISHING TEMPLET.—A templet shaped to fit between the head and base of the rail and used to determine whether the rail section is accurately formed in the fishing spaces to receive the joint bars.

TRAIN.—A series of pairs or sets of rolls connected together and driven by the same motor or engine.

TESTING

COMPRESSIVE STRENGTH.—The maximum compressive stress which a material is capable of sustaining.

DUCTILITY.—That physical property of a material which permits permanent distortion without rupture. The percentages of elongation and of reduction of area are measures of ductility and usually vary inversely with the tensile strength.

ELASTIC LIMIT.—The greatest unit stress which a material will sustain without a permanent deformation remaining after complete release of the forces producing the stress.

ELONGATION.—The per cent of change from the original length of a test specimen when tested to rupture in tension.

HARDNESS.—That physical property which enables a material to resist indentation or abrasion.

LADLE TEST INGOT.—Manual, page 138.

MACROGRAPH.—A graphic reproduction of any object magnified 10 diameters or less. When it is desired to indicate that it is a photographic reproduction, the term "photomacrograph" may be employed.

MAGNIFICATION.—The ratio of the size of the image to that of the object. Magnification is generally expressed in "Diameters", thus "×100" or "100 diameters".

MICROGRAPH.—Manual, page 140.

MODULUS OF ELASTICITY.—The ratio, within the elastic limit of a material, of unit stress to corresponding unit strain or deformation.

PERMANENT SET.—The strain or deformation remaining in a body after being stressed beyond the elastic limit.

PROPORTIONAL LIMIT.—The greatest unit stress which a material will sustain without a deviation from the law of proportionality of stress to strain.

REDUCTION (or Contraction) OF AREA.—The per cent of change in area of the cross-section of a test specimen at point of rupture when tested in tension.

STRAIN.—The change in the form of a body which accompanies a stress.

Stress.—The sum of the forces acting in the interior of a body which resist external forces tending to change its form or shape.

Stress is measured in force per unit area (pounds per square inch, kilograms per square millimeter, etc.).

Tensile Strength.—The maximum tensile stress which a material is capable of sustaining.

Tolerance.—An allowable variation from dimensions or requirements specified.

Yield Point.—That unit stress in a material at which there occurs a marked increase in strain without an increase in stress.

Rail in Track

Batter.—The deformation of the surface of the head of the rail in the immediate vicinity of the end.

Canting of Rail.—The inclination inwardly of the rail, effected by the use of inclined tie plates or by inclined dapping of the ties.

End Chipping.—The loosening of the metal on the top or gage side of the end of a rail.

End Overflow.—A projection of metal into the joint gap at the top or side of the head of the rail.

Fishing Space.—The space between the head and base of a rail occupied by the joint bar.

Joint Bar.—A steel member, embodying beam-strength and stiffness in its structural shape and material; commonly used in pairs for the purpose of joining rail ends together, and holding them accurately, evenly and firmly in position with reference to surface and gage-side alinement.

Joint Gap.—The distance between the ends of contiguous rails in track, measured at a point ⅝ inch below the top of the rail on the outside of the head.

Spring Washer.—A member designed to prevent backward movement of the nut and looseness in the bolted members of a rail-joint due to wear, stretch, rust or other deterioration.

Rail Failures

Broken Base.—Any break in the base of a rail.

Compound Fissure.—Bulletin 347, page 16; Bulletin 367–8, page 15.

Crushed Head.—Manual, page 181.

Damaged.—Any rails broken or injured by wrecks, broken, flat or unbalanced wheels, slipping or similar causes.

Detail Fracture.—A progressive transverse fracture originating at the surface of the head. It should not be confused with a transverse fissure.

Flowed Head.—A rolling out of the metal on top of the head toward the sides without showing any indication of a breaking down of the head structure.

Horizontal Split Head.—Bulletin 347, page 16, omit "(formerly termed horizontal fissure)."

Ordinary Break.—Any partial or complete fracture (square or angular break) in which there is no transverse or compound fissure and in which none of the other defects or damage described under this heading are visible.

Piped Rail.—Manual, page 139.

Split Web.—A longitudinal crack visible along the side of the web and extending into or through it.

Transverse Fissure.—A progressive transverse fracture starting from a center or nucleus inside of the head of the rail from which the fracture spreads. The broken rail will show a smooth oval or round spot within the head, substantially at right angles to the axis of the rail, which will be bright when first exposed to the air. The nucleus will show a typical crystalline fracture and the growing portion a typical detail fracture.

Vertical Split Head.—A split along or near middle of the head and extending into or through it. A crack or rust streak may show under the head close to the web, or pieces may be split off the side of the head.

Rail Specifications.—Manual, pages 148 to 157 incl. Bulletin 327, page 11; 356, pages 8 and 9; 367–8, page 15.

Title—*Present:* "Standard Specifications for Open-Hearth Carbon Steel Rail-1925." *Proposed:* "Specifications for Open-Hearth Steel Rails."

Section 1. *Present:*

Access to Works

1. Inspection and tests shall be made at the works of the manufacturer before shipment, and the works management shall afford all reasonable facilities for determining the satisfactory quality of the rails accepted.

Proposed:

Access to Works

1. Inspection and tests shall be made at the works of the manufacturer before shipment, and the works management shall afford all reasonable facilities for determining the quality of the rails produced.

Section 5. *Present:*

Physical Qualities

5. Ductility and resistance to impact will be determined by the standard A.R.E.A. drop testing machine, with test specimens from four feet to six feet long cut from the top of the "A" rails from the second, middle and last full ingots of each heat. The distance between supports shall be three feet for sections under 106 lb. For sections 106 lb. and over it shall be four feet.

Temperature of the test pieces must not exceed 100 deg. Fahr.

Section 6. *Present:*

Drop Test

6. The test specimens shall be placed preferably base upwards on the supports and subjected to one blow from the tup falling free from the following heights.

For 70– 80 lb. rail, inclusive	17 ft.
For 81– 90 lb. rail, inclusive	18 ft.
For 91–100 lb. rail, inclusive	19 ft.
For 101–120 lb. rail, inclusive	20 ft.
For 121–140 lb. rail, inclusive	22 ft.

If all these specimens endure the above tests without fracture, all the rails of the heat will be accepted subject to final inspection for surface, section and finish.

If one of the three specimens fail, all the "A" rails of the heat will be rejected. Specimens shall then be cut from the bottom end of the same "A" rails or the top end of the "B" rails and tested. If any of these tests fail, the "B" rails of the heat will be rejected. Three additional specimens shall then be taken from the bottom end of the "B" rails or the top end of the "C" rails. If all these tests stand, the balance of the heat will be accepted. If any of these tests fail, the entire heat shall be rejected.

Proposed:

Ductility and Resistance to Impact

5. (a) Ductility and resistance to impact will be determined by the standard A.R.E.A. drop testing machine, with test specimens from four feet to six feet long cut from the top of the "A" rails from the second, middle and last full ingots of each heat. Temperature of the test specimens shall not exceed 100 deg. Fahr. The distance between supports shall be three feet for sections under 106 lb. For sections 106 lb. and over it shall be four feet.

The test specimens shall be placed preferably base upwards on the supports and subjected to one blow from the tup falling free from the following heights for rails of the nominal weights indicated:

For 70– 80 lb. rail, inclusive	17 ft.
For 81– 90 lb. rail, inclusive	18 ft.
For 91–100 lb. rail, inclusive	19 ft.
For 101–120 lb. rail, inclusive	20 ft.
For 121–140 lb. rail, inclusive	22 ft.

(b) If all these specimens withstand the above tests without fracture, all the rails of the heat will be accepted subject to final inspection for surface, section and finish.

If one of the three specimens fails, all the "A" rails of the heat will be rejected. Specimens shall then be cut from the bottom end of the same "A" rails or the top end of the "B" rails of the same ingots and tested. If any of these specimens fail, the "B" rails of the heat will be rejected. Three additional specimens shall then be taken from the bottom end of the "B" rails or the top end of the "C" rails of the same ingots. If none of these specimens fail, the balance of the heat will be accepted subject to final inspection for surface, section and finish. If any of these specimens fail, the entire heat will be rejected.

Section 16 (a), **Branding:**

Change weight and section number from 11025 to 11225.
Change year rolled from 1930 to 1934.

Section 16 (b). *Present:*

The heat number and the ingot number as rolled shall be stamped in the web of each rail where it will not be covered by the joint bars. The data used in stamping and arrangement thereof shall be as shown in the following Typical Stamping.

Proposed:

The heat number, the rail letter, and the ingot number as rolled, shall be hot stamped in the web of each rail where it will not be covered by the joint bars. The data used in stamping and arrangement thereof shall be as shown in the following Typical Stamping.

Renumber Sections 7 to 20 and references thereto.

Rail Inspection.—Manual, page 152.

Title—*Present:* "Rail Inspection." *Proposed:* "Recommended Practice for Rail Inspection."

Section 1. *Present:*

(I) Inspection Force

Rail inspectors shall be selected with care and men not familiar with rolling mill practice shall not be sent to inspect rails except under the supervision of an experienced rail inspector. As far as possible the inspections shall be made by the same men, as they become familiar with the methods of manufacture peculiar to each mill, for no two mills follow the same procedure even though owned by the same company.

(1) Chief Rail Inspector.
(2) Three or more assistant inspectors as size of mill and rate of rolling may require.
(3) One or more checkers, depending upon rapidity of loading.
(4) One chemist if check analyses are made in mill laboratory.

Section 1. *Proposed:*

(1) Inspection Force

The rail inspection force shall consist of the following: One Chief Rail Inspector and such assistants as may be required.

Chief Rail Inspector and necessary qualified assistants shall be selected with care and men not familiar with rolling mill practice shall not be allowed to inspect rails except under supervision of an experienced rail inspector.

Standard Locations for Tensile Test Pieces and for Boring for Chemical Analyses, Bulletin 327, page 12.

Change title to read: "Standard Locations for Tension Test Specimens and for Boring for Chemical Analyses."

Rail Record Forms—Manual, pages 174–5.

(1) Change to read as follows:

The forms listed below and illustrated on pages ... to ... are considered essential and are recommended for keeping records of rail purchased and in track.

For reporting results of Mill Inspection and Shipments.

401–A, Report of Chemical and Physical Examination of Rails.
401–B, Certificate of Inspection.
401–C, Report of Shipment.

For reporting and recording Failures in Track.

402–A, Report of Rail Failure in Main Track.
402–C, Yearly Summary of Rail Failures.
402–E, Statement of Transverse Fissure Rail Failures.

Miscellaneous.

402–D, Statement of Rails in Main Tracks.
403–B, Diagram of Lines of Wear.

This change carries with it the elimination of the following forms, as the Committee has found these forms are not being used to any extent by its members if at all:

402–B, Monthly Summary of Rail Failures.
403–A, Diagram of Location of Rails.
403–C, Record of Wear.

It is recommended that the "Explanation of Forms" on pages 174 and 175 be eliminated from the Manual and the title of each form be shown on the page on which the form is illustrated with such explanation as may be necessary as follows:

401–A, Title:
To be prepared by the Railroad Representative to show results of chemical, physical and other tests of rails on which acceptance or rejection is based.

401–B, Title:
To be prepared by the Railroad Representative to show classification, number, length and tonnage of rails accepted, number rejected and cause of rejection.

401–C, Title:
To be prepared by the Railroad Representative to show classification and number of rails of each length and total weight loaded into each car for shipment. When properly checked by the receiving officer it furnishes the basis for the payment of the invoice.

402–A, Title:
To be prepared by Section Foreman after each failure of a rail in main track. This is the basic report from which quarterly or yearly statements of rail failures are made up.

402–C, Title:
This form to be used for making annual report of rail failures to the Association of American Railroads.

402–E, Title:
This form to be used for making quarterly report of transverse fissure failures to Association of American Railroads.

402–D, Title:
Suggested form for keeping record of type, weight and age of rail in track.

403–B, Title:
Card form for platting outline of worn rail.

SPECIFICATIONS FOR OPEN-HEARTH STEEL GIRDER RAILS OF PLAIN, GROOVED AND GUARD TYPES, Manual, pages 153–157.

These specifications were first prepared in 1926, in collaboration with the American Electric Railway Association, since merged in the American Transit Association.

They have been carefully checked against the latest adoptions of the latter association and the following changes are recommended to bring them into conformity:

Section 403, **Weight** to read:

(a) The weight of the rails per yard, as calculated, shall be maintained as nearly as possible after conforming to the requirements specified in Section 401.

(b) A variation of 0.5 per cent from the calculated weight of section as applied to entire order will be allowed.

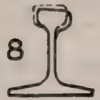
(c) Rail accepted will be paid for according to actual weight.

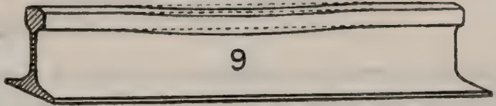
GIRDER RAIL SECTIONS, Manual, page 158.

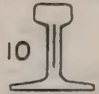
Paragraph (1):

The Committee recommends the insertion of the words *italicized* to make the last sentence read as follows:

Vertical Split Head—A vertical split through or near the middle of the head, and extending into or through it. A crack or rust streak may show under the head close to the web or pieces may be split off the side of the head. See Fig. 6 and diagrams 4, 5, 6 and 7.

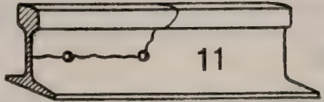


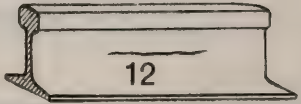




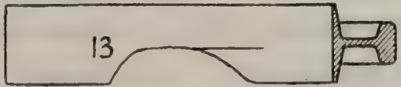
Crushed Head—A "Flattening" or crushing down of the head. See diagrams 8 and 9.

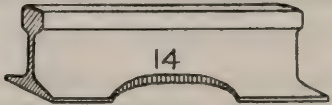
Piped Rail—One with vertical split, usually in the web, due to failure of the sides of the shrinkage cavity in the ingot to unite in rolling. See diagram 10.



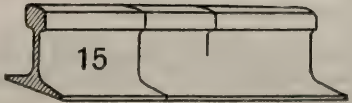


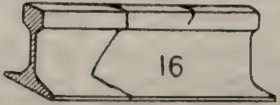
Split Web—A lengthwise crack along the side of the web and extending into or through it. See diagrams 11 and 12.





Broken Base—Any break in the base of a rail. See diagrams 13 and 14.





Square or Angular Break—Any partial or complete break in which there is no sign of a fissure, and in which none of the defects listed above can be seen. See diagrams 15 and 16.

Damaged Rail—Any rail broken or injured by wrecks, broken, flat, or unbalanced wheels, slipping or similar causes.

Size 8½x11 Inches

Form 152 A

NAME OF RAILROAD

REPORT OF RAIL FAILURE IN MAIN TRACK

Div. ---------- Dist. ---------- Section ---------- Report No. ---------- Date ----------

1. Brand ---------- 2. Stamping ----------
Wt. and Sec. No. Type Kind of Steel Manufacturer Mill Yr. Rolled Mo. Rolled Heat No. Rail Letter Ingot No.

3. Location: M. P.------ ----+ -------Rails
4. Nearest Station ----------
5. Mo. and Yr. laid---- -----Rail length---------
6. Which track---------- Which rail----------
7. Tangent or curve------ - Degree curve-------

8. High or low rail----------
9. New or second hand when laid----------
10. Was rail in track circuit----------
11. Was signal set at stop by break----------
12. Signal number ----------

13. Found by ----------
14. Date and time----------
15. Temperature ----------
16. Date last patrol----------
17. Date removed ----------

18. Rail used in place of rail removed:

Brand ----------Stamping ----------
Wt. and Sec. No. Type Kind of Steel Manufacturer Mill Yr. Rolled Mo. Rolled Heat No. Rail Letter Ingot No.

19. Describe failure, and flaws or defects, and state cause as nearly as possible ----------

20. If rail was "Damaged," describe, state cause, if known, and No. of train, engine or car causing damage----------

21. If accident or delay to trains was caused by failure, state circumstances and number of train and engine----------

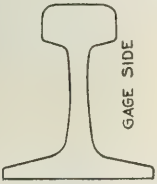


FIG. 1

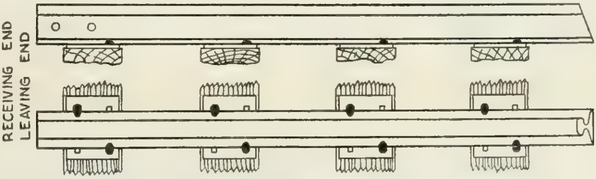


FIG. 2

22. On Fig. 1 and 2 above, draw defects and lines of break or partial break. On Fig. 1 sketch shape and position with respect to gage side and show dimensions, if transverse fissure.

23. On Fig. 2, (a) Show distance from end of rail to break or defect and tie spacing at break. (b) Where track carries traffic in one direction only, show if break is nearest Receiving or Leaving End by crossing out other words at end of figure.

Correct: Approved:

---------- Title ---------- Title

INSTRUCTIONS

A. Foremen must fill in this form for each rail removed from main tracks account of being broken, defective or damaged, as shown in the "Description of Rail Failures" on back of form, and send it to the Roadmaster or Supervisor on the day a broken rail is found, or on the day a damaged or defective rail is removed. Foremen will check type of failure on back of form.

B. "Main Tracks" has same meaning as in "Book of Rules," and includes "Single Track," "Double Track" and "Three or More Tracks."

C. In Question 3 show the number of rails, or feet if required, the failed rail is from the milepost in direction mileposts are numbered.

D. The "Brand" is rolled in raised figures and letters on the web of the rail; following shows a typical brand:

11225	RE.	O.H	ILLINOIS — G	1934	IIIIII
(Wt. & Sec. No.)	(Type)	(Kind of Steel)	(Manufacturer & Mill)	(Year)	(Month)

Where manufacturer has but one mill the name of the mill is not always shown. The kind of steel may be "B" (Bessemer); "O.H." (Open Hearth). Month rolled may be indicated by vertical or slanting lines, figures or letters.

E. The "Stamping" is stamped in depressed figures and letters on the other side of the web. Where rail is rolled from special steel the kind is shown near the heat number and may be "N" (Nickel); "C N" (Chrome Nickel); "F T" (Ferro-Titanium); "M M" or "I M" (Medium Manganese); or "H T" (Heat Treated); following shows a typical stamping:

63345	E	17
(Heat Number)	(Rail Letter)	(Ingot No.)

(Over)

DESCRIPTION OF RAIL FAILURES

FOREMAN WILL CHECK TYPE OF FAILURE ON FIGURE OR DIAGRAM BELOW

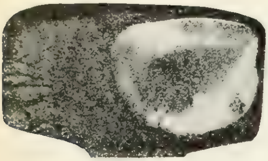


FIG. 3
Transverse Fissure

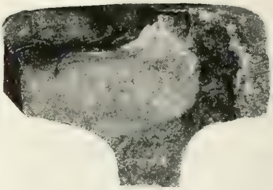


FIG. 4
Compound Fissure

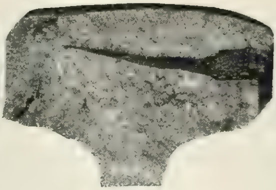


FIG. 5
Horizontal Split Head

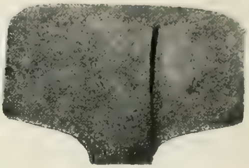
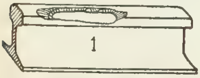
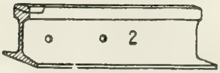


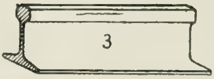
FIG. 6
Vertical Split Head

Transverse Fissure—A crosswise break starting from a center or nucleus inside the head of the rail from which it spreads outward. The broken rail will show either a bright or dark, round or oval smooth area around the nucleus. See Fig. 3.

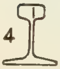
Compound Fissure—A horizontal split head which in spreading turns up or down in the head of the rail. See Fig. 4.

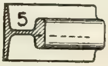


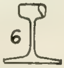


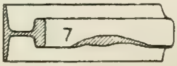


Horizontal Split Head—A horizontal break beginning inside the head of the rail and spreading outward; usually indicated on the side of the head by a lengthwise seam or crack or by flow of the metal. See Fig. 5 and diagrams 1, 2 and 3.

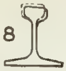


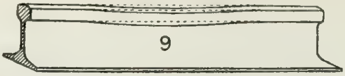


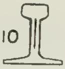




Vertical Split Head—A vertical split through or near the middle of the head, and extending into or through it. A crack or rust streak may show under the head close to the web or pieces may be split off the side of the head. See Fig. 6 and diagrams 4, 5, 6 and 7.

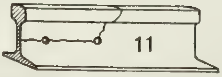


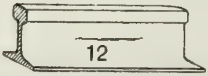




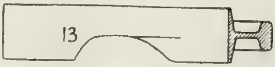
Crushed Head—A "Flattening" or crushing down of the head. See diagrams 8 and 9.

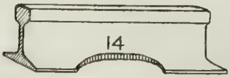
Piped Rail—One with vertical split, usually in the web, due to failure of the sides of the shrinkage cavity in the ingot to unite in rolling. See diagram 10.



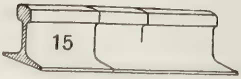


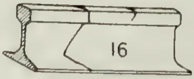
Split Web—A lengthwise crack along the side of the web and extending into or through it. See diagrams 11 and 12.





Broken Base—Any break in the base of a rail. See diagrams 13 and 14.





Square or Angular Break—Any partial or complete break in which there is no sign of a fissure, and in which none of the defects listed above can be seen. See diagrams 15 and 16.

Damaged Rail—Any rail broken or injured by wrecks, broken, flat, or unbalanced

FOREMAN WILL CHECK TYPE OF FAILURE ON FIGURE OR DIAGRAM BELOW

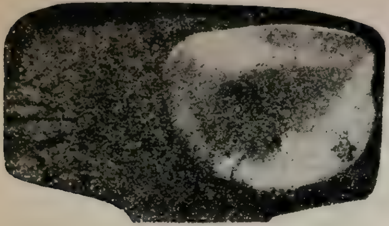


FIG. 3
Transverse Fissure

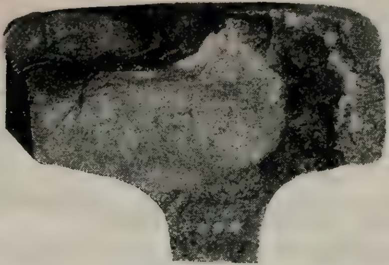


FIG. 4
Compound Fissure

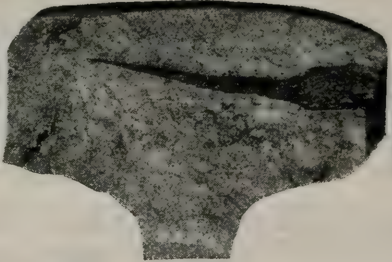
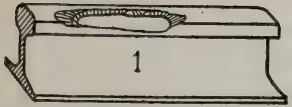


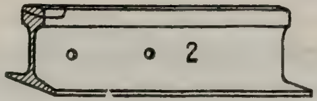
FIG. 5
Horizontal Split Head

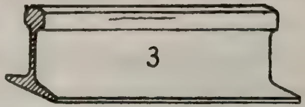
FIG. 6
Vertical Split Head

Transverse Fissure—A crosswise break starting from a center or nucleus inside the head of the rail from which it spreads outward. The broken rail will show either a bright or dark, round or oval smooth area around the nucleus. See Fig. 3.

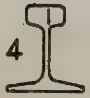
Compound Fissure—A horizontal split head which in spreading turns up or down in the head of the rail. See Fig. 4.

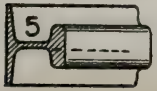


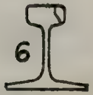


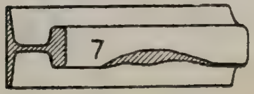


Horizontal Split Head—A horizontal break beginning inside the head of the rail and spreading outward; usually indicated on the side of the head by a lengthwise seam or crack or by flow of the metal. See Fig. 5 and diagrams 1, 2 and 3.









To most economically meet these requirements the following sections of Girder Rails, *which are adapted for use with AAR wheel flanges,* Joint Bars and accessories are recommended.

The Committee recommends the inclusion of Girder Guard Rail Section—149-lb. RE 7–A, Manual, page 159, and Joint Bars 128-lb. RE 7–A., Manual, page 161, and information pertaining to drilling and punching of same in the list of previously recommended sections as follows:

Paragraph (2): Insert "Grooved" after "Girder".

Between Paragraphs (2) and (3) insert new Paragraph (3)—"Girder Guard Rail Section, 149-lb. RE 7–A."

Paragraph (3): Insert "Grooved" after "Girder".

Between Paragraphs (4) and (5) insert new Paragraph (6)—"Joint Bars, 128-lb. RE 7–A. to be used with 128-lb. RE 7–A. Girder Grooved Rail Section and 149-lb. RE 7–A. Girder Guard Rail Section."

Paragraph 6, 2nd line, change 9A to 7A.

Paragraph (7), third line after "Section" insert: "and in 7 inch Girder Rail construction the use of the 149-lb. RE 7–A. Section Girder Guard Rail which fishes with the 128-lb. RE 7–A. Section."

Paragraph (9), second line after "Section" insert "and the 149-lb. RE 7–A. Section." Second line, change 9A to 7A.

Between Paragraphs (10) and (11) insert a new paragraph (13)—*Joint Bars* of the Sections shown as 128-lb. RE 7–A. joint bars to be used with the 128-lb. RE 7–A. Section and 149-lb. RE 7–A. Section, 26 inches long, with bolt holes punched 2½ inches —4 inches—4 inches—5 inches—4 inches—2½ inches.

Renumber paragraphs.

TABLES OF BOLT DIMENSIONS—Bulletin 327 (Supplement to Manual), pages 12 to 17.

These tables are the joint work of a Sectional Committee of the American Standards Association and have been approved by that organization. In 1934 (Vol. 35, page 877 of Proceedings) the AREA, in connection with the adoption of standard joint bars for 112-lb. and 131-lb. rail, approved by letter-ballot, changing the requirements in Column L of Table 1, "Length Under Head" reading—

"From 3″ to 6″ by steps of ¼ inch and
From 3″ to 10″ by steps of ½ inch, to read
From 3″ to 7″ by steps of ¼ inch and
From 7″ to 10″ by steps of ½ inch"

and in Table 3 changing the thickness of recessed nut for one inch bolt from 1⅛″ to 1⅜″. In view of the origin of these tables there is some question about the propriety of making changes in them without the approval of the American Standards Association and the following method of handling is recommended:

Page 12, Bulletin 327: Modify paragraph under heading "Design for Track Bolts" to read—

> These designs were prepared under date of January, 1930, by the Sectional Committee on the "Standardization of Bolt, Nut and Rivet Proportions" of the American Standards Association, on which Committee the Rail Committee is represented. Since their adoption the American Railway Engineering Association has approved the use of a one-inch bolt varying in length by steps of one-fourth inch up to seven inches (see Table 1) and a recessed nut with nominal thickness of 1⅜ inches and depth of recess of ⅜ inch (see Table 3).

In Table 1 place an asterisk before the phrase "From 6 to 10 inches by steps of ½ inch," in Column L and immediately below the table an asterisk followed by "For length of 1 inch bolt for use with Standard RE 112-lb. and RE 131-lb. rail see Joint Bar Assembly drawings pages ... and ...."

In Table 3 place an asterisk in front of the figures 1⅛″ in the column headed "Recessed-Nominal" and an asterisk immediately under the table followed by: "For thickness of recessed nuts and depth of recess for 1 inch bolts for use with Standard RE 112-lb. and RE 131-lb. rail see Joint Bar Assembly drawing pages ... and .. Tolerance shall be determined in accordance with ²Note."

Elimination of the following material from the Manual is recommended for the reasons stated:

Plan of Drop Test Machine—Manual, page 165.

The essential requirements of the drop test machine are fully brought out in the rail specifications. All rail mills are equipped with drop test machines. The drawing is not a working plan. Detail dimensions where given are indistinct and hard to read.

Rail Batter—Manual, pages 190 to 193 inclusive.

This material is not entirely in accord with present-day knowledge of the subject of batter and its elimination from the Manual is recommended. Other information regarding batter will be presented for insertion in the Manual as the Committee's study of the subject develops.

Revision of Form 402–A, Report of Rail Failure in Main Track—Manual, pages 180–181.

Revision of this form referred to in last year's report has been completed. Many questions no longer considered necessary, and others usually answered in a routine way have been omitted. The form has been otherwise simplified and the illustrations and diagrams of rail defects improved so that it is much easier for the foreman to make out. It is expected that arrangements will be made whereby the Association will be able to furnish electrotypes of this form to individual railroads desiring to use it. Your Committee recommends adoption of the revised form for printing in the Manual.

Form to be inserted.

Specifications for Quenched Carbon Steel and Alloy Steel Track Bolts—Manual, pages 170–172.

Last year your Committee presented revised specifications under the above title. It was stated that effort would be made to get the approval of the American Society for Testing Materials, whose specifications are used by a number of railroads, in order to make them acceptable to as many users as possible. Conferences have been held with representatives of the ASTM and the American Institute of Bolt and Nut Manufacturers and some adjustments have been necessary, the principal one being the provision for two grades of carbon steel bolts. Your Committee believes, however, that the specifications are an improvement over those now in the Manual and over the old ASTM specifications. They have been adopted as a tentative standard by that organization and adoption by this Association is recommended.

SPECIFICATIONS FOR HEAT-TREATED CARBON-STEEL AND ALLOY-STEEL TRACK BOLTS

Scope

1. These specifications cover two grades of heat-treated carbon-steel, also alloy-steel track bolts.

Manufacture

Process

2. (a) The steel for the bolts shall be made by either or both of the following processes: open-hearth or electric-furnace.

(b) The steel for the nuts shall be made by one or more of the following processes: open-hearth, electric-furnace, or acid-bessemer.

Chemical Properties and Tests

Chemical Composition

3. (a) The steel for the bolts shall conform to the following requirements as to chemical composition:

	Carbon Steel	*Alloy Steel**
Carbon, min., per cent	0.30	. . .
Phosphorus, max., per cent	0.04	0.04
Sulphur, max., per cent	0.06	0.05

(b) The steel for the nuts shall conform to the screw steel grades of ASTM specifications for commercial quality, hot-rolled bar steel, Serial Designation A–107, latest issue.

(c) When high strength nuts are specified, the steel for same shall conform to a carbon range of min. 0.40 per cent, max. 0.55 per cent.

---

* The type of alloy to be used shall be agreed upon between the manufacturer and the purchaser.

Ladle Analysis

4. (a) A carbon determination shall be made of each melt of bessemer steel, and determinations for manganese, phosphorus and sulphur representing the average of the melts applied for each 8-hour period.

(b) An analysis of each heat or melt of open-hearth or electric-furnace steel shall be made to determine the percentage of carbon, alloy when used, manganese, phosphorus and sulphur.

(c) The analyses prescribed in Paragraphs (a) and (b) shall be made by the manufacturer from test ingots taken during the pouring of each heat or melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 3.

Check Analysis

5. An analysis may be made by the purchaser from a finished bolt representing each heat or melt. The phosphorus content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

PHYSICAL REQUIREMENTS

Tension Tests

6. (a) Tension test specimens shall be taken from the finished bolts and shall conform to the following minimum requirements as to tensile properties:

	Carbon Steel		
	Grade 1	*Grade 2*	*Alloy Steel*
Ult. Tens. str., lb. per sq. in.	100,000	110,000	115,000
Yield Point, lb. per sq. in.	70,000	80,000	85,000
Elongation in 2 in. per cent	12	14	15
Reduction of Area, per cent	25	35	40

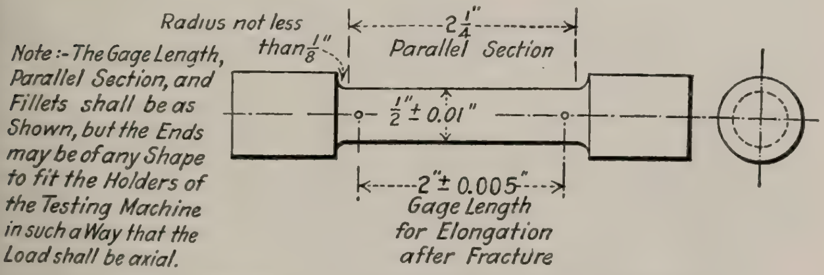

Radius not less than 1/8"
2 1/4"
Parallel Section
Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

(b) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine operated at a cross-head speed not in excess of ⅛ inch per minute. The tensile strength shall be determined at a speed not in excess of 1½ inches per minute.

(c) The tension test specimen taken from the finished bolt shall conform to the dimensions shown in Fig. 1.

Number of Tests

7. (a) One tension, one bend, and one strip test shall be made from each lot of 50 kegs or fraction thereof.

(b) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(c) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (a) and any part of the fracture is more than ¾ inch from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Bend Tests

8. (a) Full-size carbon-steel track bolts, Grade 1 and Grade 2, shall stand being bent cold through 45 degrees around a pin, the diameter of which is equal to the diameter of the bolt, without cracking on the outside of the bent portion. If the bend test specimen breaks in the threaded portion, a retest shall be allowed.

(b) Full-size alloy-steel track bolts shall stand being bent cold through 90 degrees around a pin, the diameter of which is equal to the diameter of the bolt, without cracking on the outside of the bent portion. If the bend test specimen breaks in the threaded portion, a retest shall be allowed.

Strip Test

9. The threads of the nut must not 'strip' when the bolt, with nut fully mounted, is tested in tension to its yield point, the load being applied to the head of the bolt and the bearing side of the nut.

Retest

10. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension, and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

DESIGN AND TOLERANCE

Tolerance

11. (a) The bolts and nuts shall conform to the plans specified by the purchaser, subject to the following variations:

(b) The nominal size of rolled thread bolts shall be the over-all diameter of the rolled threads.

(c) The outside diameter of the finished rolled threads shall not exceed the diameter of the shank of a cut thread bolt of corresponding size.

The diameter of the rolled threads shall not exceed the diameter of the shank by more than 1/16 inch for bolts ⅞ inch in diameter and under, nor more than 3/32 inch for bolts 1 inch in diameter and over.

Shank diameter for cut thread bolt	plus 1/64 in. or minus 1/32 in.
Neck dimensions	plus 1/32 in. or minus 1/32 in.
Length under head	plus 1/8 in. or minus 1/8 in.
Height and diameter of head	plus 1/16 in. or minus 1/16 in.
Nut—Width	minus 0.05 × thread diameter of bolt
Nut—Height	plus or minus (0.016 × thread diameter of bolt + 0.012)

MANUFACTURE

Finish

12. The bolts and nuts shall be neatly formed and free from fins or nicking. The head of the bolt shall be concentric with and firmly jointed to the shank, with the under side at right angles to the axis of the bolt. It shall be free from injurious defects and shall have a workmanlike finish.

Threads and Thread Fit

13. The threads on bolts may be rolled or cut and shall be of the American Standard shape as shown in the American Standard Screw Thread tables, B1, latest issue. The nut shall have a handfree fit from two to five turns in starting on the bolt, shall be wrench tight the remainder of the screw length of the nut, and shall show a minimum resistance of twenty pounds and a maximum of seventy pounds applied to a 24 inch wrench when the nut is fully engaged. Before packing, nuts shall be screwed on the bolts enough turns to hold them in place until used.

MARKING AND INSPECTION

Marking

14. (a) A letter or brand indicating the manufacturer together with the numeral 1 for Grade 1, numeral 2 for Grade 2, and the initial A for alloy bolts, shall be pressed on the head of the bolt when it is formed.

(b) All containers shall be marked by the manufacturer as follows:

(1) Name of manufacturer.
(2) Material (Grade 1, Grade 2, or Alloy).
(3) Size of bolt (diameter and length).
(4) Weight.

Inspection

15. The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bolts and nuts ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to enable him to satisfy himself that the bolts and nuts are being furnished in accordance with these specifications. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

16. (a) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(b) Bolts and nuts which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer will be notified.

Rehearing

17. Samples tested in accordance with Section 5 which represent rejected bolts shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may make claim for a hearing within that time.

SPECIFICATIONS FOR HIGH CARBON STEEL JOINT BARS, Manual, page 166.

SPECIFICATIONS FOR QUENCHED CARBON STEEL JOINT BARS, Manual, page 167.

Inquiry made of the various railroads in 1934 developed the fact that a substantial number of roads have been purchasing joint bars under the specifications of the American Society for Testing Materials in preference to those of the American Railway Engineering Association. Your Committee has, therefore, undertaken jointly with the ASTM the matter of revision of the specifications of both organizations for the purpose of improving them and making them generally acceptable to the roads.

These revised specifications, which are submitted for adoption and printing in the Manual, while not yet acted upon by the ASTM have been accepted by its Sub-Committee handling this subject in all but one particular, namely, that of tolerance in the straightness of the bar. It will be noted these specifications permit an upward camber of 1/32 inch in the length of the bars and a horizontal sweep of 1/32 inch in the length of the 24 inch bar and of 1/16 inch in the length of the 36 inch bar, whereas the ASTM committee has heretofore agreed to a permissible upward camber of 1/16 inch for the 36 inch bar and a horizontal sweep of 1/16 inch for both lengths.

Your Committee hopes to be in position to advise more definitely regarding the attitude of the ASTM when this report is presented to the Convention.

SPECIFICATIONS FOR HIGH CARBON STEEL JOINT BARS

Scope

1. This specification covers high carbon steel joint bars for general use in standard railroad tracks.

Process

2. The steel shall be made by the open hearth process.

Discard

3. Sufficient discard shall be made from each ingot to insure freedom from piping and undue segregation.

Heating

4. Joint bars shall be uniformly heated for punching, slotting and shaping.

Chemical Composition

5. The steel shall conform to the following requirements as to chemical composition:

Carbon	not under 0.45
Phosphorus	not over 0.04

Ladle Analysis

6. An analysis of each heat or melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from drillings taken at least ⅛″ beneath the surface of a test ingot obtained during the pouring of the heat or melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and the percentages of carbon and phosphorus shall conform to the requirements specified in Section 5.

Check Analysis

7. An analysis may be made by the purchaser from a finished joint bar representing each heat or melt. The percentage of carbon thus determined shall conform to the requirement specified in Section 5, and the phosphorus content shall not exceed that specified by more than 25 per cent.

Tension Tests

8. The joint bars shall conform to the following minimum requirements as to tensile properties:

Tensile Strength, lb., per sq. in.	85,000
Elongation in 2 in., per cent	15

Bend Tests

9. The bend test specimen specified in Section 11 shall stand being bent cold through 90 deg. around a pin the diameter of which is equal to three times the thickness of the specimen, without cracking on the outside of the bent portion.

Optional Bend Test

10. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that prescribed in Section 9. A piece of the finished bar shall stand being bent cold through 45 deg. around a pin the diameter of which is equal to three times the greatest thickness of the section, without cracking on the outside of the bent portion.

Test Specimens

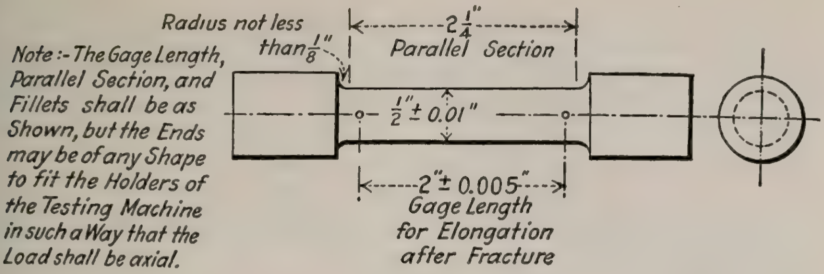
11. Tension and bend test specimens shall be taken from the finished joint bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. Bend test specimens may be ½ in. square in section or rectangular in section with two parallel faces as rolled and with corners rounded to a radius not over 1/16 in.

Number of Tests

12. (a) One tension and one bend test shall be made from each heat or melt.

(b) If any test specimen shows defective machining or develops flaws it may be discarded and another specimen substituted.

(c) If the percentage of elongation of any tension test specimen is less than that specified in Section 8 and any part of the fracture is more than ¾ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.


Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Workmanship

13. The joint bars shall be smoothly rolled, true to templet and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and slotting shall conform to the dimensions specified by the purchaser. A variation of 1/32 in. plus or minus from specified size of holes, of 1/16 in. plus or minus from specified location of holes and of ⅛ in. plus or minus from specified length of joint bar will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in the vertical plane shall not exceed 1/32 in. in the length of the 24 inch or 36 inch bar. The horizontal sweep shall not exceed 1/32 in. in the length of the 24 inch bar or 1/16 in. in the length of the 36 inch bar.

Finish

14. The finished joint bars shall be free from injurious defects and shall have a workmanlike finish.

Marking and Stamping

15. The name or brand of the manufacturer, the section number, and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars and a portion of this marking shall appear on each finished joint bar. A serial number representing the heat or melt shall be hot stamped on the outside of the web of each bar near one end.

Inspection

16. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

17. (a) Unless otherwise specified, any rejection based on tests made in accordance with Section 7 shall be reported within five working days from the receipt of samples.

(b) Joint bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing

18. Samples tested in accordance with Section 7, which represent rejected joint bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

SPECIFICATIONS FOR QUENCHED CARBON STEEL JOINT BARS

Scope

1. This specification covers heat treated carbon steel joint bars for general use in standard railroad tracks.

Process

2. The steel shall be made by the open-hearth process.

Discard

3. Sufficient discard shall be made from each ingot to insure freedom from piping and undue segregation.

Heating and Quenching

4. Joint bars shall be uniformly heated for punching, slotting and shaping and subsequently quenched.

Chemical Composition

5. The steel shall conform to the following requirements as to chemical composition:

Carbon	0.35 to 0.60 per cent
Manganese	Not over 0.80 per cent
Phosphorus	Not over 0.04 per cent

Ladle Analysis

6. An analysis of each heat or melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from drillings taken at least ⅛ in. beneath the surface of a test ingot obtained during the pouring of the heat or melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and the percentages of carbon, manganese and phosphorus shall conform to the requirements specified in Section 5.

Check Analysis

7. An analysis may be made by the purchaser from a finished joint bar representing each heat or melt. The percentages of carbon and manganese thus determined shall conform to the requirements specified in Section 5, and phosphorus content shall not exceed that specified by more than 25 per cent.

Tension Tests

8. (a) The joint bars shall conform to the following minimum requirements as to tensile properties:

Tensile Strength, lb. per sq. in.	100,000
Yield Point, lb. per sq. in.	70,000
Elongation in 2 in., per cent	12
Reduction of Area, per cent	25

(b) The yield point shall be determined by the drop of the beam or halt in the gage of the testing machine operated at a cross-head speed not to exceed ⅛ in. per minute. The tensile strength shall be determined at a speed of head not to exceed 1½ in. per minute.

Bend Tests

9. The bend test specimen specified in Section 11 shall stand being bent cold through 90 deg. around a pin the diameter of which is equal to three times the thickness of the specimen, without cracking on the outside of the bent portion.

Optional Bend Test

10. If preferred by the manufacturer and approved by the purchaser, the following bend test may be substituted for that described in Section 9. A piece of the finished bar shall stand being bent cold through 45 deg. around a pin the diameter of which is equal to three times the greatest thickness of the section, without cracking on the outside of the bent portion.

Test Specimens

11. Tension and bend test specimens shall be taken from the middle of the head at the center of the finished joint bars. Tension test specimens shall conform to the dimensions shown in Fig. 1. Bend test specimens may be ½ in. square in section or rectangular in section with two parallel faces as rolled and with corners rounded to a radius not over 1/16 in.

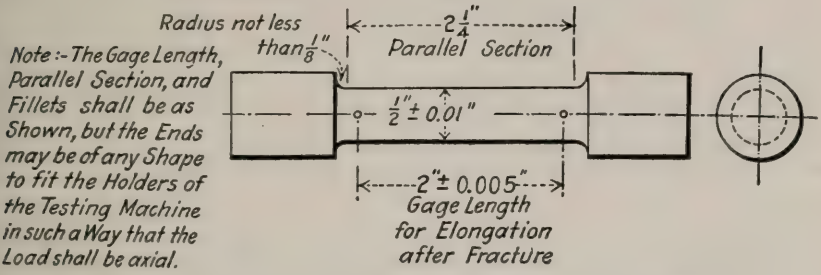

Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.
Radius not less than 1/8"
2 1/4"
Parallel Section
1/2" ± 0.01"
2" ± 0.005"
Gage Length for Elongation after Fracture

FIG. 1.—Standard 2-in. Gage Length Tension Test Specimen.

Number of Tests

12. (a) One tension and one bend test shall be made from each heat or melt.

(b) If any test specimen shows defective machining or develops flaws it may be discarded and another specimen substituted.

(c) If the percentage of elongation of any tension test specimen is less than specified in Section 8 and any part of the fracture is more than ¾ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests

13. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such test lot not more than twice, in which case two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.

Workmanship

14. The joint bars shall be smoothly rolled, true to templet and shall accurately fit the rails for which they are intended. The bars shall be sheared to length, and the punching and slotting shall conform to the dimensions specified by the purchaser. A variation of 1/32 in. plus or minus from specified size of holes, of 1/16 in. plus or minus from specified location of holes and of ⅛ in. plus or minus from specified length of joint bar will be permitted. Any variation from a straight line in a vertical plane shall be such as will make the bars high in the center. The maximum camber in the vertical plane shall not exceed 1/32 in. in the length of the 24 inch or 36 inch bar. The horizontal sweep shall not exceed 1/32 in. in the length of the 24 inch bar or 1/16 in. in the length of the 36 inch bar.

Finish

15. The finished joint bars shall be free from injurious defects and shall have a workmanlike finish.

Marking and Stamping

16. The name or brand of the manufacturer, the section number, and the year of manufacture shall be rolled in raised letters and figures on the side of the rolled bars and a portion of this marking shall appear on each finished joint bar. A serial number representing the heat or melt shall be hot stamped on the outside of the web of each bar near one end.

Inspection

17. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection

18. (a) Unless otherwise specified, any rejection based on tests made in accordance with Section 7 shall be reported within five working days from the receipt of samples.

(b) Joint bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing

19. Samples tested in accordance with Section 7, which represent rejected joint bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Appendix B

(2) FURTHER RESEARCH, INCLUDING DETAILS OF MILL PRACTICE AND MANUFACTURE AS THEY AFFECT RAIL QUALITY AND RAIL FAILURES, GIVING SPECIAL ATTENTION TO TRANSVERSE FISSURE FAILURES, COLLABORATING WITH RAIL MANUFACTURERS' TECHNICAL COMMITTEE

Earl Stimson, Chairman, Sub-Committee; A. F. Blaess, W. C. Barnes, C. B. Bronson, E. E. Chapman, R. Faries, J. V. Neubert, G. J. Ray, W. P. Wiltsee, L. Yager.

The Rails Investigation, which is a cooperative investigation by the Board of Trustees of the University of Illinois, the Rail Manufacturers' Technical Committee and the Association of American Railroads, ended its fifth year December 31st, 1935, which was the last year under the contract of March 18th, 1931, between the three parties.

The state of the investigation at the end of the five years was such that it was highly desirable to continue the work for another year, so as to bring it to a well rounded conclusion. Fortunately there was an unexpended balance in the amount of money provided for by the contract sufficient to carry on the work for the additional year. It was agreed to continue the work on this basis and the necessary funds for the purpose have been made available by the Rail Manufacturers' Technical Committee and the Association of American Railroads.

A progress report of this investigation was made by H. F. Moore, Research Professor of Engineering Materials, in charge of the investigation, University of Illinois. This report appears in the June 1935 Bulletin 376. A further statement of the progress of the investigation will be made by Professor Moore at the time this report is presented at the coming annual convention of the Association.

Appendix C

(3) RAIL FAILURE STATISTICS FOR 1934

By W. C. Barnes, Engineer of Tests, Rail Committee

The Rail Failure Statistics for the year ended December 31, 1934, appearing in this report have been compiled in accordance with the standard method of basing the failure rates on mile years of service in track.

The reported tonnages and track miles of rollings for 1929 and succeeding years embodied in these statistics are as follows:

Year Rolled	*Tons*	*Track Miles*
1929	1,719,426	9,777
1930	1,243,659	7,032
1931	793,977	4,417
1932	241,719	1,375
1933	189,320	1,011
Totals	4,188,101	23,612

Table 1 shows the average failures per 100 track miles of rail in service which occurred in one to five years service on the rail reported from rollings of 1929 to 1933 inclusive, from all mills together with similar rates of older rollings taken from previous reports which include both Bessemer and open-hearth rails. The 1929 rollings, whose period of observation is now concluded, show an average of 121.2 failures per 100 track miles during the five year period, an increase of 44.8 over the rate reported last year for the 1928 rollings. The failure rate for the 1929 rollings is the highest of any rolling rolled within the last 11 years with the exception of that for 1926. Both service and detected failures are included in this table.

Fig. 1 shows diagrammatically the five year averages from Table 1.

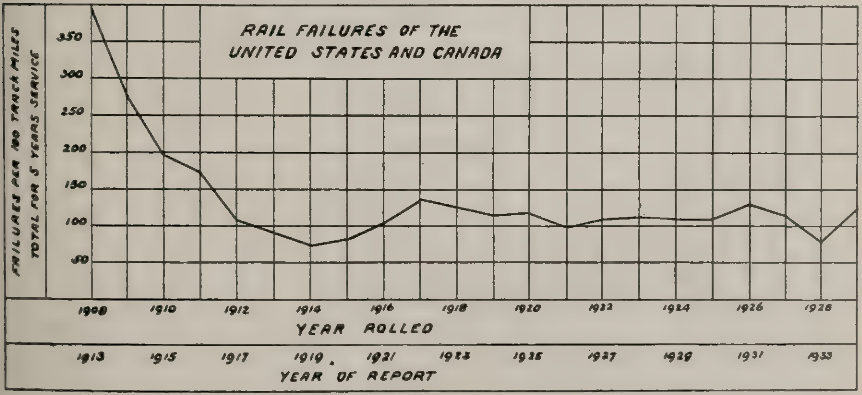


FIG. 1.

Table 2 presents the accumulated failures and failure rates of rail from each of the mills for each of the rollings of 1929 and succeeding years, unweighted for traffic. This Table presents the data in the same manner as it was presented last year, showing failure rates separately for service and for service plus detected failures.

Fig. 2 shows diagrammatically the failure rates for combined service and detected failures per 100 track miles of the 1929 rollings from Table 2, which have completed their five year service period. Five year rates for earlier rollings are reproduced from previous reports.

Fig. 3 shows diagrammatically the Table 2 failure rates per 100 track miles per year, separately for service and service plus detected failures, for each of the 1929 and subsequent rollings, by mills, unweighted for traffic. It can be forecast from this Table that the All Mill failure rates which will appear in next year's report will be considerably improved over those here shown, as the 1929 rollings which were particularly poor at a number of the mills will have then disappeared from the record.

Fig. 4 shows diagrammatically the comparative performances of the mills from the same data that underlie Fig. 3 except that average traffic density factors have been introduced into the final computations using the method described in detail in previous reports. No claim is made for the entire accuracy for this system of rating but it does give more consideration to the work which the failed rails from the respective mills were called upon to perform than does the system of rating on which Fig. 3 is based.

Table 3 shows the average weights of rail from the various mills and from all mills included in these statistics.

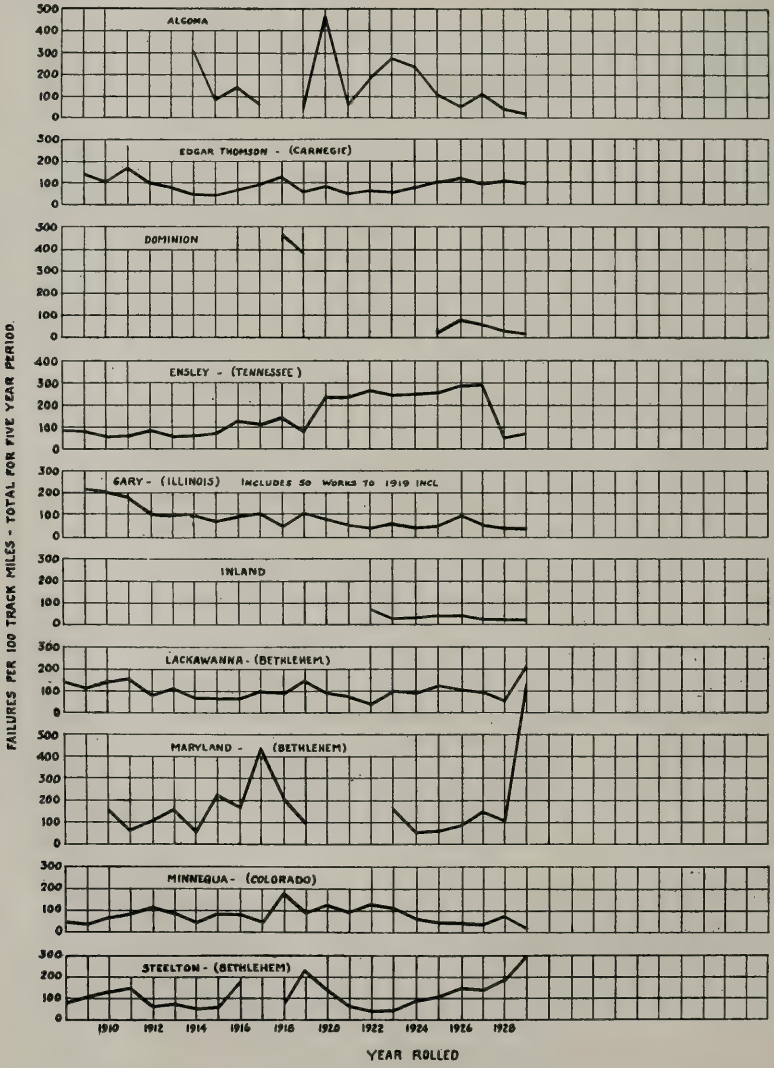
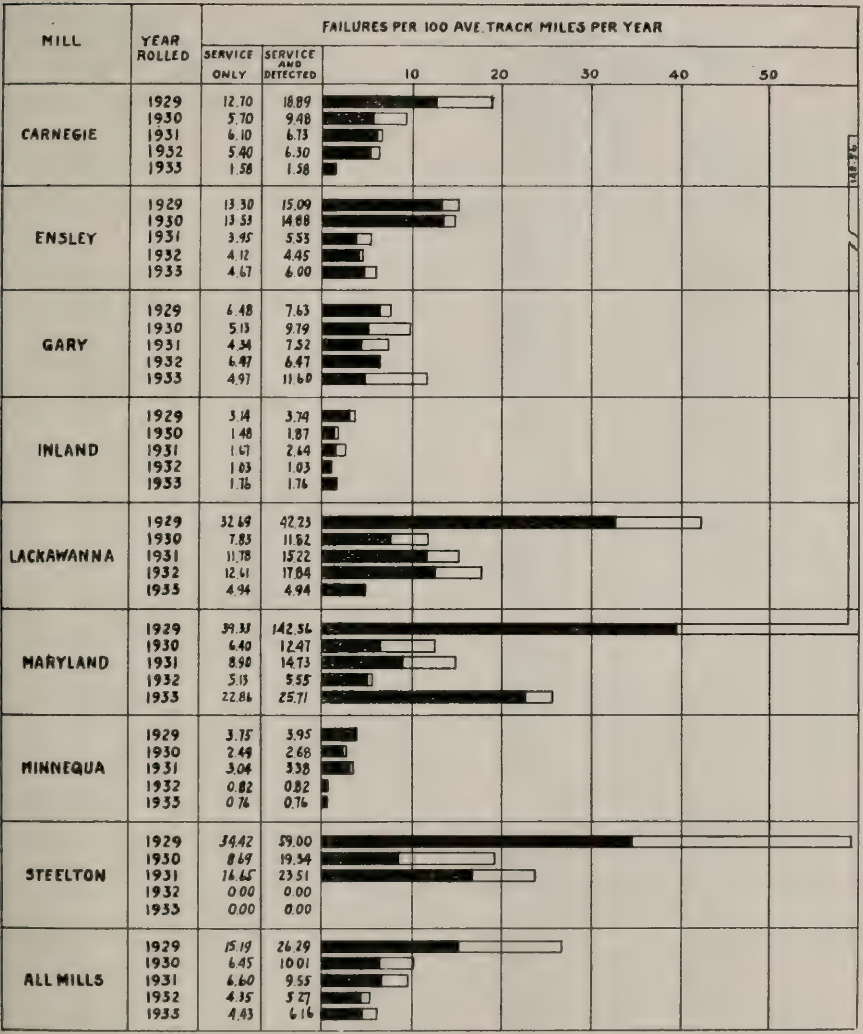
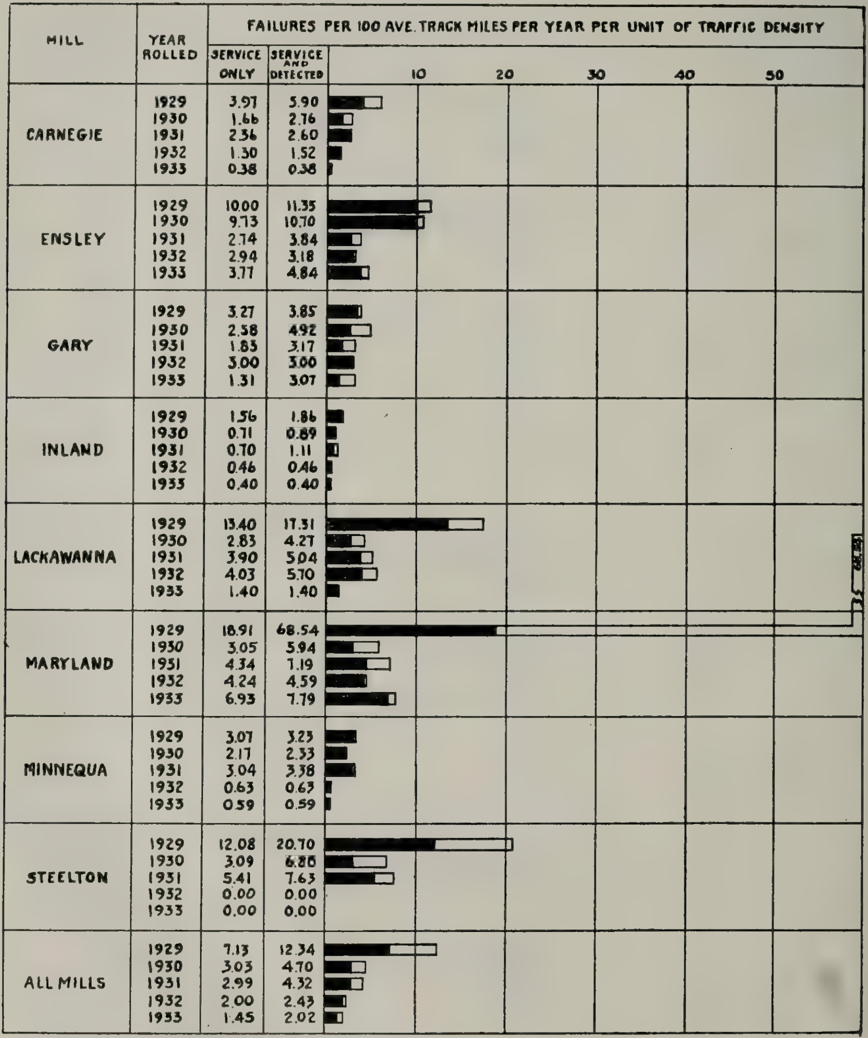


Fig. 2.—Record of Failures per 100 Track Miles for Five Year's Service for Rollings from 1908 to 1929. (Service and Detected Failures Included)



MILL	YEAR ROLLED	SERVICE ONLY	SERVICE AND DETECTED
CARNEGIE	1929	12.70	18.89
	1930	5.70	9.48
	1931	6.10	6.73
	1932	5.40	6.30
	1933	1.58	1.58
ENSLEY	1929	13.30	15.09
	1930	13.53	14.88
	1931	3.95	5.53
	1932	4.12	4.45
	1933	4.67	6.00
GARY	1929	6.48	7.63
	1930	5.13	9.79
	1931	4.34	7.52
	1932	6.47	6.47
	1933	4.97	11.60
INLAND	1929	3.14	3.74
	1930	1.48	1.87
	1931	1.67	2.64
	1932	1.03	1.03
	1933	1.76	1.76
LACKAWANNA	1929	32.69	42.23
	1930	7.83	11.82
	1931	11.78	15.22
	1932	12.61	17.84
	1933	4.94	4.94
MARYLAND	1929	39.33	142.56
	1930	6.40	12.47
	1931	8.90	14.73
	1932	5.13	5.55
	1933	22.86	25.71
MINNEQUA	1929	3.75	3.95
	1930	2.49	2.68
	1931	3.04	3.38
	1932	0.82	0.82
	1933	0.76	0.76
STEELTON	1929	34.42	59.00
	1930	8.69	19.34
	1931	16.65	23.51
	1932	0.00	0.00
	1933	0.00	0.00
ALL MILLS	1929	15.19	26.29
	1930	6.45	10.01
	1931	6.60	9.55
	1932	4.35	5.27
	1933	4.43	6.16

FIG. 3.—Failure Rates from Date Rolled to Dec. 31, 1934, by Mills. (Service and Detected Failure Rates Shown Separately.)



MILL	YEAR ROLLED	SERVICE ONLY	SERVICE AND DETECTED
CARNEGIE	1929	3.97	5.90
	1930	1.66	2.16
	1931	2.36	2.60
	1932	1.30	1.52
	1933	0.38	0.38
ENSLEY	1929	10.00	11.35
	1930	9.13	10.10
	1931	2.14	3.84
	1932	2.94	3.18
	1933	3.77	4.84
GARY	1929	3.27	3.85
	1930	2.58	4.92
	1931	1.83	3.17
	1932	3.00	3.00
	1933	1.31	3.07
INLAND	1929	1.56	1.86
	1930	0.71	0.89
	1931	0.70	1.11
	1932	0.46	0.46
	1933	0.40	0.40
LACKAWANNA	1929	13.40	17.31
	1930	2.83	4.27
	1931	3.90	5.04
	1932	4.03	5.10
	1933	1.40	1.40
MARYLAND	1929	18.91	68.54
	1930	3.05	5.94
	1931	4.34	7.19
	1932	4.24	4.59
	1933	6.93	7.79
MINNEQUA	1929	3.07	3.23
	1930	2.17	2.33
	1931	3.04	3.38
	1932	0.63	0.63
	1933	0.59	0.59
STEELTON	1929	12.08	20.70
	1930	3.09	6.86
	1931	5.41	7.63
	1932	0.00	0.00
	1933	0.00	0.00
ALL MILLS	1929	7.13	12.34
	1930	3.03	4.70
	1931	2.99	4.32
	1932	2.00	2.43
	1933	1.45	2.02

FIG. 4.—Failure Rates from Year Rolled to Dec. 31, 1934, by Mills, Altered by Traffic Density Factors. (Service and Detected Failure Rates Shown Separately.)

Table 1.—AVERAGE FAILURES PER 100 TRACK MILES—ALL MILLS

(Both service and detected failures are included)

Year Rolled	Years Service				
	1	2	3	4	5
1908					398.1
1909				224.1	277.8
1910			124.0	152.7	198.5
1911		77.0	104.4	133.3	176.3
1912	28.9	32.1	49.3	78.9	107.1
1913	12.5	25.8	44.8	69.5	91.9
1914	8.2	19.8	32.9	50.9	74.0
1915	8.9	19.0	34.2	53.0	82.4
1916	11.8	29.2	47.7	70.6	105.4
1917	21.6	38.9	66.0	110.5	137.0
1918	8.9	27.6	54.0	92.8	125.4
1919	14.8	39.4	73.7	104.8	115.7
1920	14.2	32.4	63.1	84.5	119.6
1921	10.9	34.9	56.9	70.9	98.9
1922	15.9	34.8	55.2	80.4	110.0
1923	14.3	33.2	57.6	86.0	114.1
1924	14.0	33.4	58.3	82.0	110.7
1925	15.5	36.6	58.3	76.6	110.7
1926	17.1	41.2	64.6	102.6	131.3
1927	18.4	37.7	69.5	94.6	112.4
1928	11.0	28.0	45.8	57.4	76.4
1929	14.1	36.8	55.9	82.7	121.2
1930	7.8	12.8	22.4	37.6	
1931	9.1	19.7	32.3		
1932	4.5	11.8			
1933	6.2				

TABLE 2.—ACCUMULATED FAILURES AND FAILURE RATES FROM DATE ROLLED TO DEC. 31, 1934, BY MILLS, COMPUTED BY MILE YEARS OF RAIL IN SERVICE. ORIGINAL TRACK MILES ARE INCLUDED FOR INFORMATION ONLY.

Year Rolled	Original Trk. Mls.	FAILURES TO DEC. 31, 1934					Original Trk. Mls.	FAILURES TO DEC. 31, 1934				
		SERVICE		SERV. & DET.				SERVICE		SERV. & DET.		
		Total	Per 100 Trk. Mls. Per Yr.	Total	Per 100 Trk. Mls. Per Yr.	Per 100 Trk. Mls.		Total	Per 100 Trk. Mls. Per Yr.	Total	Per 100 Trk. Mls. Per Yr.	Per 100 Trk. Mls.
ALGOMA							**DOMINION**					
1929	772.00	139	3.6	139	3.6	18.0	63.49	3	0.9	11	3.5	17.3
1930	472.76	43	2.3	43	2.3		63.88	9	3.5	12	4.7	
1931	347.13	245	23.6	249	23.9		46.74	10	7.1	10	7.1	
1932	61.60	20	16.3	23	18.7		0.00	0	0.0	0	0.0	
1933	0.00	0	0.0	0	0.0		0.00	0	0.0	0	0.0	
EDGAR THOMSON (CARNEGIE)							**ENSLEY (TENNESSEE)**					
1929	1,393.73	860	12.7	1,279	18.9	94.5	1,143.39	737	13.3	836	15.1	75.5
1930	860.89	184	5.7	306	9.5		1,003.09	522	13.5	574	14.9	
1931	591.48	96	6.1	106	6.7		750.55	88	3.9	123	5.5	
1932	188.65	18	5.4	21	6.3		272.54	22	4.1	24	4.4	
1933	200.77	3	1.6	3	1.6		151.56	7	4.7	9	6.0	
GARY (ILLINOIS)							**INLAND**					
1929	2,015.27	626	6.5	737	7.6	38.2	688.82	104	3.1	124	3.7	18.7
1930	1,664.21	319	5.1	608	9.8		627.87	35	1.5	44	1.9	
1931	936.47	105	4.3	182	7.5		277.94	12	1.7	19	2.6	
1932	161.43	10	6.5	10	6.5		101.95	2	1.0	2	1.0	
1933	190.89	9	5.0	21	11.6		86.30	1	1.8	1	1.8	
LACKAWANNA (BETHLEHEM)							**MARYLAND (BETHLEHEM)**					
1929	957.42	1,445	32.7	1,866	42.2	211.1	570.74	984	39.3	3,567	142.6	712.8
1930	579.55	169	7.8	255	11.8		404.81	96	6.4	187	12.5	
1931	375.83	130	11.8	168	15.2		345.15	69	8.9	140	14.7	
1932	173.57	41	12.6	58	17.8		122.26	12	5.1	13	5.5	
1933	111.92	4	4.9	4	4.9		69.49	16	22.9	18	25.7	

	MINNEQUA (COLORADO)						STEELTON (BETHLEHEM)					
1929	1,204.86	223	3.7	235	3.9	19.7	967.65	1,459	34.4	2,501	59.0	295.0
1930	807.04	79	2.5	85	2.7		548.11	178	8.7	396	19.3	
1931	329.15	26	3.0	29	3.4		416.68	187	16.6	264	23.5	
1932	242.83	4	0.8	4	0.8		50.55	0	0.0	0	0.0	
1933	132.21	1	0.8	1	0.8		67.45	0	0.0	0	0.0	
	ALL MILLS (Excl. Algoma & Dominion)						ALL MILLS (Incl. Algoma & Dominion)					
1929	8,941.88	6,438	15.2	11,145	26.3		9,777.37	6,580	14.1	11,295	24.2	121.2
1930	6,495.57	1,582	6.4	2,455	10.0		7,032.21	1,634	6.1	2,510	9.4	37.6
1931	4,023.25	713	6.6	1,031	9.5		4,417.12	968	8.1	1,290	10.8	32.3
1932	1,313.78	109	4.3	132	5.3		1,375.38	129	4.9	155	5.9	11.8
1933	1,010.59	41	4.4	57	6.2		1,010.59	41	4.4	57	6.2	6.2
Totals----	21,785.07	8,883		14,820			23,612.67	9,352		15,307		

TABLE 3.—AVERAGE WEIGHTS OF RAILS COMPILED FROM TONNAGES USED IN THIS REPORT

Mill	1929	1930	1931	1932	1933
Algoma	101.2	101.2	114.9	99.5	--------
Dominion	126.9	126.9	107.8	------	------
Edgar Thomson (Carnegie)	120.8	122.9	124.3	128.2	127.8
Ensley (Tennessee)	101.6	103.0	101.0	101.6	103.2
Gary (Illinois)	111.0	110.2	114.6	112.1	119.8
Inland	110.8	111.5	114.2	108.6	122.7
Lackawanna (Bethlehem)	115.2	117.6	119.3	120.3	125.5
Maryland (Bethlehem)	116.2	114.9	114.9	103.7	119.2
Minnequa (Colorado)	104.2	107.3	99.9	109.3	111.1
Steelton (Bethlehem)	123.8	129.9	130.3	127.8	127.7
All Mills	111.9	112.5	114.3	111.7	119.1

Appendix D

(3) TRANSVERSE FISSURE STATISTICS FOR 1934

By W. C. Barnes, Engineer of Tests, Rail Committee

These statistics constitute a cumulative record of 85,283 transverse fissure failures that have been reported up to and including December 31, 1934. They include all fissured rails reported, whether located by actual breakage in track or detected before breakage by inspection or test. This total, however, does not represent all such failures that have occurred for the reason that while the records of some roads have been cumulative for 20 years, those of other roads are of more recent origin and furthermore some roads do not report such failures. Compound fissures and horizontal split heads (or horizontal fissures) are not included.

Table 1 corresponds with Table 1 of last year's report and shows the number of transverse fissure failures classified by roads and by year failed. It differs, however, from last year's Table 1 in that data from those roads which have discontinued reporting or which do not report service and detected failures separately have been eliminated. It is felt that this change will facilitate and give a more accurate comparison of fissure failures as between roads and be more fair to those roads which make consistent and complete reports. The service and detected failures which occurred each year are listed separately and the combined accumulated totals to December 31, 1934, are given. The total failures on any road for any year can be obtained by adding its service and detected failures for that year.

The total detected failures for 1933 listed in last year's report have been increased by 233 to include one report received too late for inclusion last year.

The accumulated grand total transverse fissure failures, service and detected, from consistently reporting roads to December 31, 1934, from all rollings, is 79,305 which is an addition during the year 1934 on these same roads of 9,820 of which 4,786 were service and 5,034 were detected failures. This represents a total increase of 1,106 failures over the corrected total of 8,714 reported in 1933. This 1,106 increase is made up of an increase of 592 service and 514 detected failures.

Fig. 1 presents graphically the total fissure failures by year failed from Table 1. The dotted line curve includes detected failures while the solid line curve excludes them. The broken line curve shows the detected fissure failures only. The steady decrease in service failures which occurred from 1929 to 1933 inclusive changed to an increase in 1934.

Table 2 shows all reported transverse fissure failures, service and detected, for each year's rollings from each mill, accumulated from year rolled to December 31, 1934, unweighted for traffic output of mills, by density of traffic or by years of service. It includes data from all reporting roads and hence includes a grand total of transverse fissure failures (85,283) which is greater than that included in Table 1. In previous reports failures in rollings prior to 1910 were shown separately but in this report, to reduce the size of the Table, the data of those older rollings which are now of minor interest are reported together instead of separately. This Table is most useful in comparing the failures in the various year's rollings from any one mill and study of this Table will disclose wide variations in the total failures in the different year's rollings of several of the mills.

Fissure failures reported since 1924 as occurring in the first year of service are as follows:

29 Failures in 1925 from 1925 Rollings, All Mills
50 " " 1926 " 1926 " " "
114 " " 1927 " 1927 " " "
58 " " 1928 " 1928 " " "
106 " " 1929 " 1929 " " "
33 " " 1930 " 1930 " " "
32 " " 1931 " 1931 " " "
3 " " 1932 " 1932 " " "
0 " " 1933 " 1933 " " "
0 " " 1934 " 1934 " " "

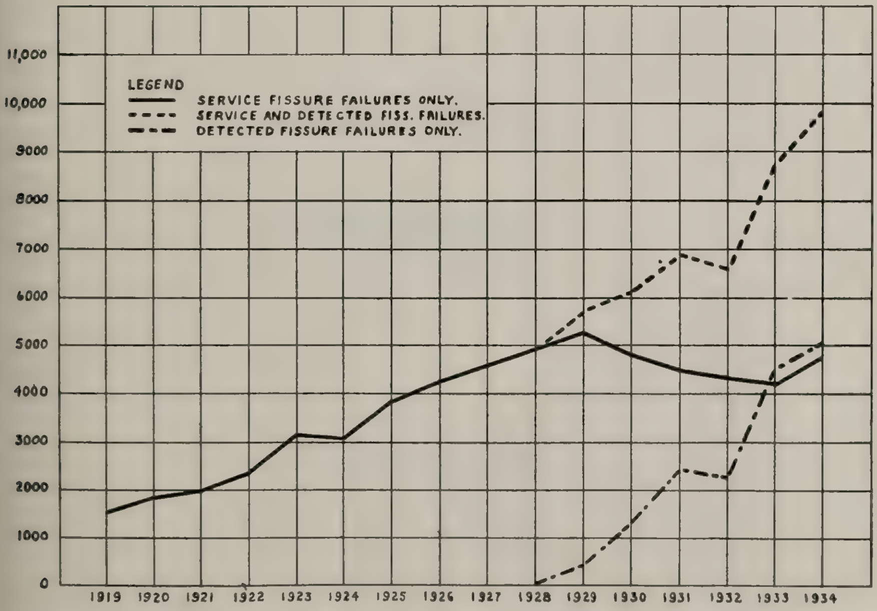


Fig. 1.—Total Fissure Failures Reported Each Year. (1930 Includes 11 Months Only)

Fig. 2 is a mill rating chart and shows separately the service and detected transverse fissure failure rates per 100 average track miles per year of each of the 1927 to 1931 rollings of each mill from date rolled to December 31, 1934, unweighted for traffic. This Fig. presents the data in the same manner as did Fig. 2 in last year's report.

Fig. 3 shows graphically the average rates of failure by mills from Fig. 2 modified by the application of average traffic density factors, the derivation of which has been explained in previous reports.

MILL	YEAR ROLLED	FISSURE FAILURE RATES PER 100 AVE. TRACK MILES PER YEAR	
		SERVICE ONLY	SERVICE AND DETECTED
CARNEGIE	1927	3.3	4.0
	1928	3.6	5.7
	1929	2.0	2.7
	1930	1.1	1.6
	1931	1.2	1.4
ENSLEY	1927	10.9	13.3
	1928	2.7	3.8
	1929	5.5	7.0
	1930	1.2	1.7
	1931	1.4	2.9
GARY	1927	2.9	4.1
	1928	0.8	1.3
	1929	0.6	1.1
	1930	3.8	8.7
	1931	2.5	6.0
INLAND	1927	1.6	4.4
	1928	1.2	3.8
	1929	0.7	2.6
	1930	0.1	1.5
	1931	0.9	2.1
LACKAWANNA	1927	8.6	13.5
	1928	6.0	9.5
	1929	5.5	9.5
	1930	0.5	0.7
	1931	0.4	0.5
MARYLAND	1927	15.2	28.4
	1928	21.2	37.1
	1929	33.5	143.0
	1930	10.2	20.6
	1931	11.4	33.3
MINNEQUA	1927	0.5	0.9
	1928	0.5	1.2
	1929	0.3	0.3
	1930	0.1	0.2
	1931	0.0	0.0
STEELTON	1927	6.3	10.0
	1928	5.9	12.6
	1929	6.2	12.1
	1930	7.4	21.4
	1931	11.3	18.9
ALL MILLS	1927	5.1	7.5
	1928	3.3	6.0
	1929	4.2	11.1
	1930	2.3	5.5
	1931	3.0	6.0

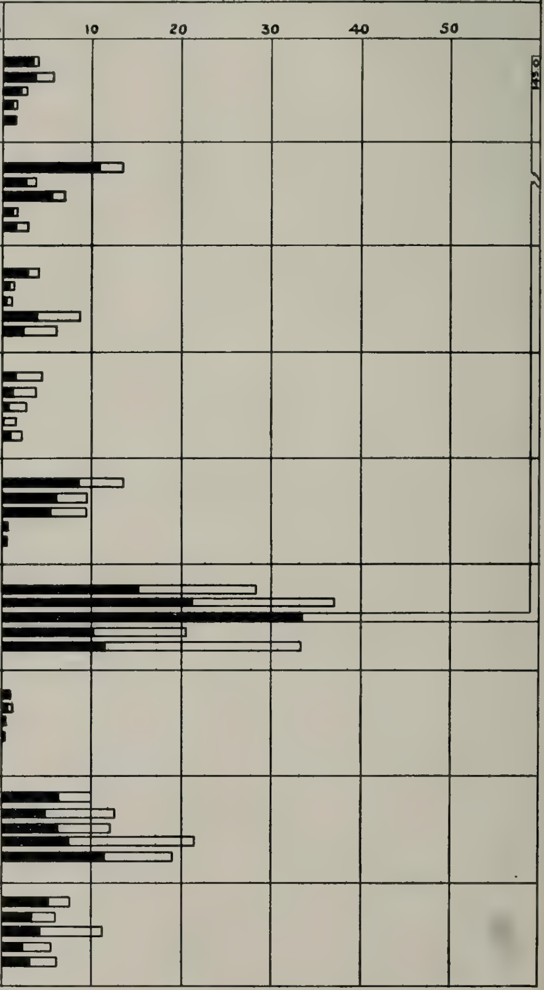
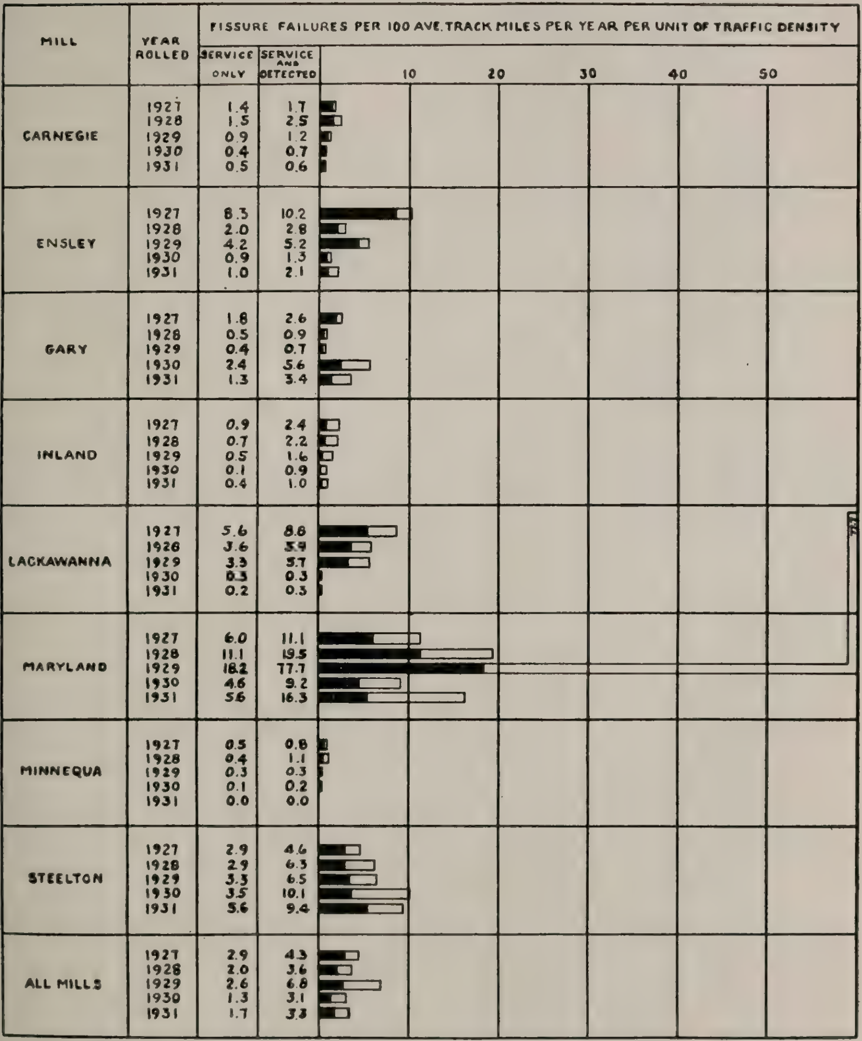


FIG. 2.—Fissure Failure Rates from Date Rolled to Dec. 31, 1934 by Mills. (Service and Detected Failure Rates Shown Separately)



MILL	YEAR ROLLED	FISSURE FAILURES PER 100 AVE. TRACK MILES PER YEAR PER UNIT OF TRAFFIC DENSITY: SERVICE ONLY	SERVICE AND DETECTED
CARNEGIE	1927	1.4	1.7
	1928	1.5	2.5
	1929	0.9	1.2
	1930	0.4	0.7
	1931	0.5	0.6
ENSLEY	1927	8.3	10.2
	1928	2.0	2.8
	1929	4.2	5.2
	1930	0.9	1.3
	1931	1.0	2.1
GARY	1927	1.8	2.6
	1928	0.5	0.9
	1929	0.4	0.7
	1930	2.4	5.6
	1931	1.3	3.4
INLAND	1927	0.9	2.4
	1928	0.7	2.2
	1929	0.5	1.6
	1930	0.1	0.9
	1931	0.4	1.0
LACKAWANNA	1927	5.6	8.8
	1928	3.6	5.9
	1929	3.3	5.7
	1930	0.3	0.3
	1931	0.2	0.3
MARYLAND	1927	6.0	11.1
	1928	11.1	19.5
	1929	18.2	77.7
	1930	4.6	9.2
	1931	5.6	16.3
MINNEQUA	1927	0.5	0.8
	1928	0.4	1.1
	1929	0.3	0.3
	1930	0.1	0.2
	1931	0.0	0.0
STEELTON	1927	2.9	4.6
	1928	2.9	6.3
	1929	3.3	6.5
	1930	3.5	10.1
	1931	5.6	9.4
ALL MILLS	1927	2.9	4.3
	1928	2.0	3.6
	1929	2.6	6.8
	1930	1.3	3.1
	1931	1.7	3.3

FIG. 3.—Fissure Failure Rates from Date Rolled to Dec. 31, 1934 by Mills, Altered by Traffic Density Factors. (Service and Detected Failure Rates Shown Separately)

TABLE 1

TRANSVERSE FISSURE FAILURES BY RAILROAD AND YEAR FAILED[a]

Roads	Service Failures																		Detected Failures[b]							Grand Total
	Prior	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930[c]	1931	1932	1933	1934	Total	1929	1930[c]	1931	1932	1933	1934	Total	
A. T. & S. F.	40	25	177	220	134	126	81	79	71	98	126	91	142	114	84	64	46	1718	--	--	--	--	13	77	90	1808
A. C. L.	--	--	--	--	--	--	--	--	11	9	27	25	21	29	37	15	33	207	--	66	--	--	69	--	135	342
Ban. & Aroos.	--	--	--	--	--	--	--	--	11	2	0	4	7	2	1	1	0	28	--	--	--	--	--	--	--	28
Boston & Albany	4	17	23	30	25	15	10	9	3	12	8	31	31	26	42	57	44	387	--	23	29	40	27	19	138	525
Boston & Maine	--	--	--	--	--	35	69	72	78	70	44	34	35	22	33	17	24	533	--	17	--	19	45	17	98	631
B. & O. [d]	--	--	--	--	9	223	306	385	268	475	431	469	372	506	383	397	328	4552	53	--	--	182	217	308	760	5312
Can. Pacific	--	4	--	8	16	59	86	158	277	174	160	108	138	106	89	88	94	1565	--	--	351	214	474	834	1873	3438
Cent. of Ga.	106	52	23	41	31	29	24	40	20	20	42	92	80	42	74	56	81	853	--	80	--	107	18	136	341	1194
C. R. R. of N. J.	--	--	--	--	--	--	--	--	--	34	58	95	73	59	40	61	85	505	--	35	111	--	--	--	146	651
C. & E. I.	--	--	--	--	--	--	--	--	4	--	22	41	18	18	28	39	23	193	28	--	59	--	74	43	204	397
C. & O. [e]	--	--	--	6	39	99	131	119	210	108	195	258	181	239	330	280	316	2511	22	376	667	323	978	584	2950	5461
C. & N. W.	--	--	--	--	--	--	--	--	85	63	47	62	101	86	110	81	99	734	16	31	110	218	110	341	826	1560
C. M. St. P. & P.	2	--	6	5	14	11	11	13	5	9	26	11	26	45	105	125	99	513	43	--	49	--	156	179	427	940
C. R. I. & P.	10	2	11	25	37	75	73	114	98	97	90	123	111	116	131	139	136	1388	20	--	18	93	13	274	418	1806
C. C. C. & St. L.	--	--	--	--	2	1	1	47	21	11	36	44	44	27	26	26	42	328	--	--	--	76	7	4	87	415
D. L. & W.	474	193	240	169	91	80	73	113	128	86	92	139	98	64	102	82	65	2289	--	--	--	--	--	173	173	2462
Erie	--	--	--	--	15	43	89	100	118	148	128	235	156	175	181	179	187	1754	27	2	1	--	75	--	105	1859
Great Northern	--	--	--	--	--	--	--	--	--	58	221	175	189	141	126	128	143	1181	--	25	--	--	6	144	175	1356
Illinois Central	11	35	121	190	372	556	419	501	614	658	615	597	439	310	281	245	275	6239	25	126	204	217	273	108	953	7192
Ind. Harbor Belt	--	--	--	--	--	1	3	3	0	0	0	0	0	0	0	0	0	7	--	--	--	--	--	--	--	7
L. & H. R.	--	--	--	1	0	4	4	16	33	10	7	8	3	11	3	4	2	106	--	--	--	--	--	--	--	106
L. & N. E.	--	--	--	--	--	32	0	0	0	0	1	0	0	6	3	2	7	51	--	--	--	--	--	16	16	67
Lehigh Valley	--	--	--	--	57	89	113	92	75	75	55	60	39	22	17	34	30	758	--	--	78	--	--	140	218	976
L. A. & S. L.	--	--	--	--	--	--	1	7	12	36	39	32	40	49	52	67	71	406	2	--	--	--	9	54	65	471
L. & N.	474	9	17	33	43	77	90	75	141	295	374	456	285	268	220	182	215	3254	101	165	--	--	358	19	643	3897
Mich. Cent.	--	--	--	--	--	2	5	11	13	10	8	15	18	20	44	15	24	185	--	--	--	--	4	36	40	225
M. K. T.	--	--	--	2	11	13	17	29	26	33	33	30	31	32	30	17	20	324	10	12	29	76	31	98	256	580
M. & O.	--	--	--	--	--	--	--	--	18	30	59	18	26	32	42	24	25	274	4	--	--	--	--	1	5	279
N. C. & St. L.	10	0	1	2	2	8	5	7	3	15	15	34	22	50	42	58	20	294	--	2	--	--	--	40	42	336
N. Y. C. (East)	415	84	88	93	136	107	126	165	233	257	295	300	209	183	152	157	128	3128	27	63	44	57	169	21	381	3509

TABLE 1—Continued

TRANSVERSE FISSURE FAILURES BY RAILROAD AND YEAR FAILED[a]

Roads	*Service Failures*																	*Detected Failures*[b]							Grand Total
	Prior	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930[c]	1931	1932	1933	1934	Total	1929	1930[c]	1931	1932	1933	1934	Total	
N. Y. C. (West)	--	--	1	18	37	16	31	62	49	44	34	54	38	50	35	51	34	554	--	21	10	9	46	34	120	674
N. Y., N. H. & H.	--	--	--	--	12	28	26	57	63	34	27	51	40	25	24	40	59	486	17	67	159	106	101	100	550	1036
N. Y. O. & W.	--	--	--	--	--	--	--	--	--	59	62	63	60	48	54	67	34	447	--	--	1	4	--	--	5	452
N. & W.	--	--	--	--	3	17	45	29	18	16	18	25	43	41	29	50	33	367	--	20	--	5	--	74	99	466
N. P.	--	--	--	--	42	39	120	161	152	184	166	160	131	171	160	126	169	1781	48	--	--	--	81	19	148	1929
P. R. R. [f]	2244	1114	1129	1106	912	656	512	787	871	747	574	584	572	426	317	344	439	13334	--	192	378	378	818	429	2195	15529
Reading	--	--	--	--	52	112	107	91	36	42	39	53	57	100	111	111	160	1071	--	--	--	--	--	--	--	1071
R. F. & P.	--	--	--	--	--	--	--	--	0	0	0	1	0	1	3	5	4	14	3	--	--	--	36	--	39	53
Rutland	--	--	--	--	--	--	--	3	2	1	0	2	3	1	0	1	0	13	--	--	--	7	--	--	7	20
Sou. Sys.	--	--	--	--	--	24	6	13	51	123	191	205	201	183	160	187	232	1576	--	--		--	--	--	--	1576
U. P. R. R.	--	--	--	36	262	557	498	473	356	289	341	406	457	446	483	450	865	5919	32	--	137	157	312	606	1244	7163
Virginian	--	--	--	--	--	--	--	--	--	--	10	12	7	24	24	28	33	138	--	--	--	--	--	--	--	138
West. Maryland	--	--	--	--	--	--	--	65	111	164	212	57	255	148	94	94	62	1262	--	--	--	--	--	106	106	1368
All Roads	3790	1535	1837	1985	2354	3134	3082	3896	4285	4596	4928	5260	4799	4464	4302	4194	4786	63227	478	1323	2435	2288	4520	5034	16078	79305

Notes—

[a] Roads no longer reporting or not reporting service and detected failures separately are omitted.

[b] Detection methods first used to any extent in 1929.

[c] 1930 data covers 11 months only.

[d] B.R.&P. included with B&O.

[e] Hocking Valley included with C&O.

[f] Long Island included with PRR.

TABLE 2

ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1934, BY YEAR ROLLED AND BY MILL

(INCLUDES FISSURED RAILS DETECTED BEFORE ACTUAL FAILURE IN TRACK)

Year	Unknown			Algoma			Saucon			Cambria			Carnegie			Colorado			Dominion			German		
Rolled	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total
Unk.	110	7	117	11		11	51	2	53	44	3	47	51	5	56	36		36	3		3			
Prior	14	3	17	32	5	37	1817	86	1903	505	3	508	350	8	358	9		9	129	13	142			
1910	15		15	12	1	13	831	26	857	121	1	122	28	3	31	433	15	448						
1911	3	1	4	14	1	15	1007	25	1032	358	4	362	60	2	62	532	64	596						
1912	14		14	8		8	161	4	165	698	23	721	75	1	76	90	22	112	63	10	73			
1913	25	1	26	8	1	9	343	3	346	621	32	653	94	2	96	49	4	53	4	1	5			
1914	2	1	3	39	5	44	149	3	152	353	13	366	42	2	44	106	12	118	15	4	19			
1915	2		2	532	44	576	342	13	355	132	1	133	54	2	56	202	11	213						
1916	1	1	2	119	9	128	386	9	395	103	4	107	94	2	96	489	32	521		1	1			
1917	4		4	6		6	267	4	271	165	3	168	79	2	81	622	105	727						
1918	2		2	420	5	425	97	7	104	96	4	100	79	3	82	119	39	158	89	15	104			
1919	1		1	457	50	507	269	27	296	20		20	24	2	26	68	27	95	62	8	70			
1920				103	9	112	74	13	87	66	2	68	101	1	102	480	119	599	1		1			
1921	1		1	74	15	89	196	6	202	179	9	188	136	7	143	203	66	269	2		2			
1922				326	113	439	131	5	136	81	2	83	203	8	211	62	7	69						
1923	96		96	311	111	422				56	3	59	185	14	199	65	14	79						
1924	66		66	370	263	633							167	22	189	58	8	66						
1925	56		56	23	16	39							242	28	270	61	14	75	6	150	156			
1926	22		22	8	21	29							469	49	518	32	19	51	37	6	43	6	2	8
1927	28		28	54	83	137							361	58	419	21	39	60		1	1			
1928	1		1	69	31	100							267	98	365	15	50	65						
1929													130	62	192	8	23	31	1		1			
1930	1		1										32	36	68	1	3	4						
1931				1	1	2							12	11	23									
1932				4		4							1	3	4									
1933																								
1934																								
Totals	464	14	478	3001	784	3785	6121	233	6354	3598	107	3705	3336	431	3767	3761	693	4454	412	209	621	6	2	8

TABLE 2—Continued

ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1934, BY YEAR ROLLED AND BY MILL

(INCLUDES FISSURED RAILS DETECTED BEFORE ACTUAL FAILURE IN TRACK)

Year	Gary*			Inland			Lackawanna**			Lorain			Maryland			Steelton			Ensley			All Mills		
Rolled	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total	Prior	1934	Total
Unk.	167	7	174	4	1	5	32	4	36				16		16	14	7	21	193	23	216	732	59	791
Prior	1022	58	1080				348	26	374	12		12	401	6	407	190	5	195	709	2	711	5538	215	5753
1910	2599	142	2741				270	21	291				127	1	128	134	1	135	164	2	166	4734	213	4947
1911	293	16	309				388	8	396				249	6	255	137	8	145	186	5	191	3227	140	3367
1912	1703	111	1814				935	33	968				201	4	205	126	13	139	137	9	146	4211	230	4441
1913	1745	100	1845				1036	38	1074	1		1	508	18	526	150	15	165	152	7	159	4736	222	4958
1914	486	46	532				796	18	814				154		154	119	9	128	240	4	244	2501	117	2618
1915	700	53	753				479	36	515				597	49	646	158	7	165	95	6	101	3293	222	3515
1916	1091	169	1260				155	8	163				586	43	629	38	5	43	280	14	294	3342	297	3639
1917	2966	470	3436				167	7	174				909	35	944	10	2	12	276	34	310	5471	662	6133
1918	823	178	1001				141	6	147				126	5	131	15	1	16	467	39	506	2474	302	2776
1919	1711	287	1998				126	10	136				100	13	113	129	6	135	683	92	775	3650	522	4172
1920	912	175	1087				220	13	233				3		3	182	12	194	245	22	267	2387	366	2753
1921	807	212	1019				193	21	214				4	1	5	319	32	351	304	66	370	2418	435	2853
1922	344	73	417	244	11	255	222	16	238				7		7	98	21	119	618	93	711	2336	349	2685
1923	1039	236	1275	143	43	186	618	54	672				8		8	171	16	187	526	65	591	3218	556	3774
1924	622	203	825	200	84	284	249	24	273				22	2	24	362	65	427	943	192	1135	3059	863	3922
1925	512	148	660	163	34	197	447	49	496				255	23	278	331	56	387	1298	215	1513	3394	733	4127
1926	796	257	1053	293	61	354	667	113	780				263	35	298	412	119	531	1353	141	1494	4358	823	5181
1927	431	220	651	66	15	81	619	118	237				636	119	755	483	164	647	896	91	987	3595	908	4503
1928	107	43	150	55	28	83	245	73	318				410	117	527	540	218	758	162	27	189	1871	685	2556
1929	45	46	91	24	12	36	254	119	373				1981	511	2492	387	158	545	251	60	311	3081	991	4072
1930	244	182	426	2	2	4	6	8	14				120	78	198	286	122	408	30	27	57	722	458	1180
1931	61	57	118	1	9	10	2	2	4				72	35	107	135	71	206	32	27	59	316	213	529
1932	1	1	2										3		3		1	1	2	11	13	11	16	27
1933		8	8																	3	3		11	11
1934																								
Totals	21227	3498	24725	1195	300	1495	8615	825	9440	13		13	7758	1101	8859	4926	1134	6060	10242	1277	11519	74675	10608	85283

*Includes South Works prior to 1920.
**Prior to 1903 was Scranton Mill of Lackawanna Iron & Steel Co.

Appendix E

THE AAR DETECTOR CAR

By W. C. Barnes, Engineer of Tests, Rail Committee

On November 14, 1935 the AAR Detector Car completed its seventh year of operation under the supervision of the Rail Committee and under the immediate direction of the writer. During this period it tested a total of 34,387 track miles of rail.

The AAR service now includes towing service, and an adjustment in rates has been made to provide for this added feature. Operating supplies such as gasoline, lubricating oil, etc., are furnished by the lessee road.

The improved Detector Car body and new Tow Car which were put into service last year have greatly improved the service rendered, reducing delays formerly occasioned by inadequate towing equipment and reducing the time required for repeat tests because of the rapid acceleration and braking that are now possible. The lessee roads have been relieved of the troublesome towing service which they previously performed and so far have not had to load the cars for shipment to the next receiving road as these cars are now capable of long distance and fast delivery on their own wheels.

The number of transverse fissures detected during the past year was unusually high, which indicates either improved operating efficiencies, greater prevalence of fissures or a combination of both.

The demand for service continues active, lease commitments usually being made four to six months in advance of delivery of the cars.

Appendix F

(4) CAUSE AND PREVENTION OF RAIL BATTER

F. M. Graham, Chairman, Sub-Committee; John E. Armstrong, W. J. Backes, W. C. Barnes, N. J. Boughton, B. Herman, E. E. Oviatt, W. H. Penfield, J. C. Patterson, R. T. Scholes, G. R. Smiley, C. P. Van Gundy.

The Committee has made a detailed study of the prevention of rail batter by various methods including heat treatment of rail ends.

Some of the results of previous studies are included in progress reports found in AREA Proceedings, page 371, Vol. 32 (1931), and page 854, Vol. 35 (1934).

Results have been observed on a large mileage distributed over various railroads where several methods of heat treatment have been used, dating back as far as 1927.

The following vertical longitudinal graph, Fig. 1, is a typical illustration of the result which can be obtained by heat treatment.

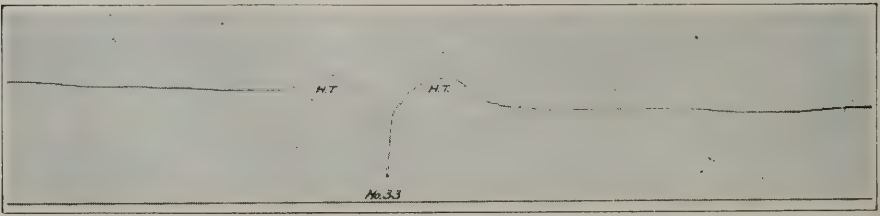


Fig. 1.—Graph of Profile of Heat Treated Rail Ends.

This profile of the top of the rail was obtained after the joint was subjected to 201 million gross tons of traffic over a four and one-half year period. The rail was 130-lb. section with six-hole heavy joint bars.

Fig. 2 shows an adjacent untreated joint in the same track, subjected to the same traffic.

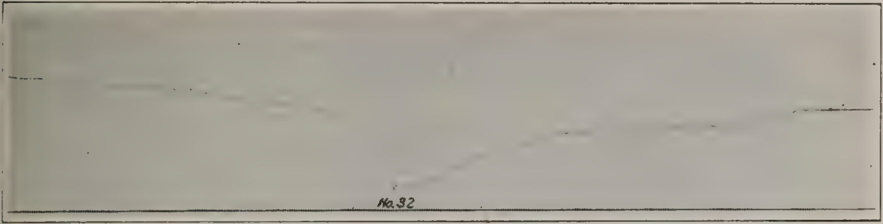


Fig. 2.—Graph of Profile of Untreated Rail Ends.

The graph shown in Fig. 1 and 2 were obtained using the following profile instrument. This instrument plots to actual scale longitudinally and to fifty times actual scale vertically. The actual distance between the vertical lines appearing at the sides of the graphs is 24 in.

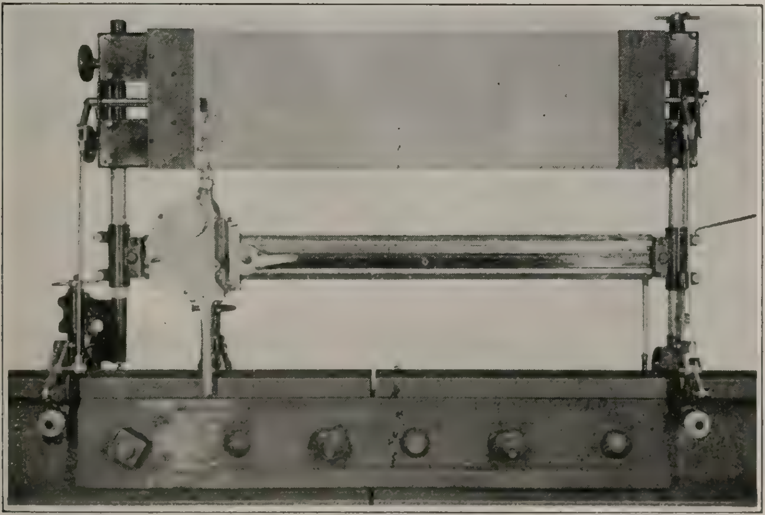


Fig. 3.—Profile Instrument Used to Produce Graphs Shown in Fig. 1 and 2.

It is not thought that the high spots at rail ends appearing in graph shown in Fig. 1 would become objectionable within the life of the rail, but, if so, they could be ground down at a nominal expense.

No other successful method of preventing rail batter has been developed, and as a result of these studies, the Committee has reached the following conclusions which it recommends for publication in the Manual under heading "Batter":

1. Objectionable batter can be prevented by the hardening of rail ends through suitable heat treatment with a Brinell hardness not exceeding 400.

2. When rails are laid, the difference in surface heights of adjacent rail ends should be corrected by grinding. After heat treatment of ends and before traffic, the hardened ends should be cross ground or slotted.

3. For the purpose of securing uniform measurements of rail batter in further studies, a rail batter gage similar to that illustrated in Fig. 4 and 5 should be used.

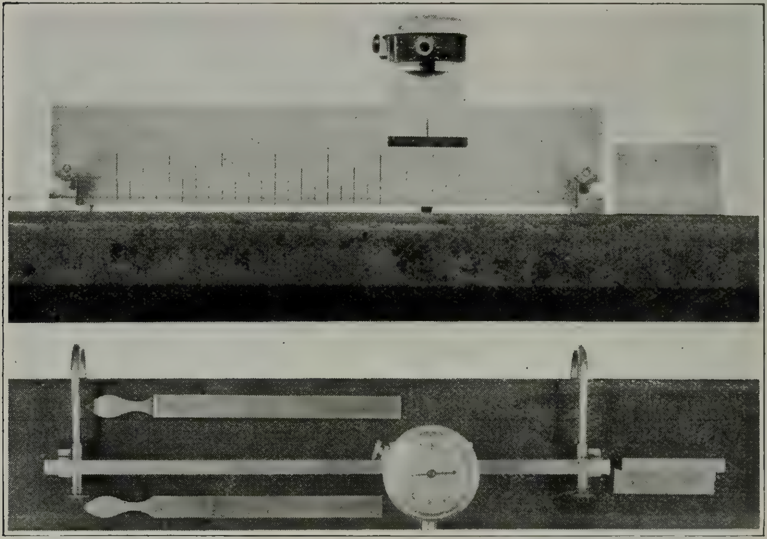


Fig. 4.—10 Inch Batter Gage.

4. This gage should be placed in the center of the width of the rail head spanning the joint. On one-way traffic the center of length of gage should be placed on the receiving rail 2-in. from the center of the joint opening. On two-way traffic, the gage should be placed with its center of length over the center of the joint opening.

5. Readings can be taken either with the dial depth gage or the taper gage as shown. The dial depth gage is to be set at zero with the master gage as shown. When a taper gage is used, it should be graduated with zero point located where the gage is 0.1-in. thick. Both should be graduated and read to 0.001-in. per graduation. Readings should be taken at extreme end of running contact on rail, one-half inch from center of joint, one inch from center of joint, and subsequent inches to the end of graduations on the gage. Joint opening in 16ths of inches should be noted at outside of rail at gage height and also minimum opening between wheel contact points at top of rail.

6. Readings should be entered on blank form similar to that shown in Fig. 6.

7. Readings for a stretch of track shall be averaged for each designated graduation on the gage furnishing an average profile. Gross tonnage figures should be furnished for period covered between readings.

8. The area in square inches between average profiles secured from measurements should be equated to the basis of 10 million gross tons of traffic and the resulting area multiplied by 1000 representing a value termed batter index.

The above report is submitted as partially complete. The Committee will continue to study other phases of the subject, including results to be obtained from the various methods of heat treatment now available.

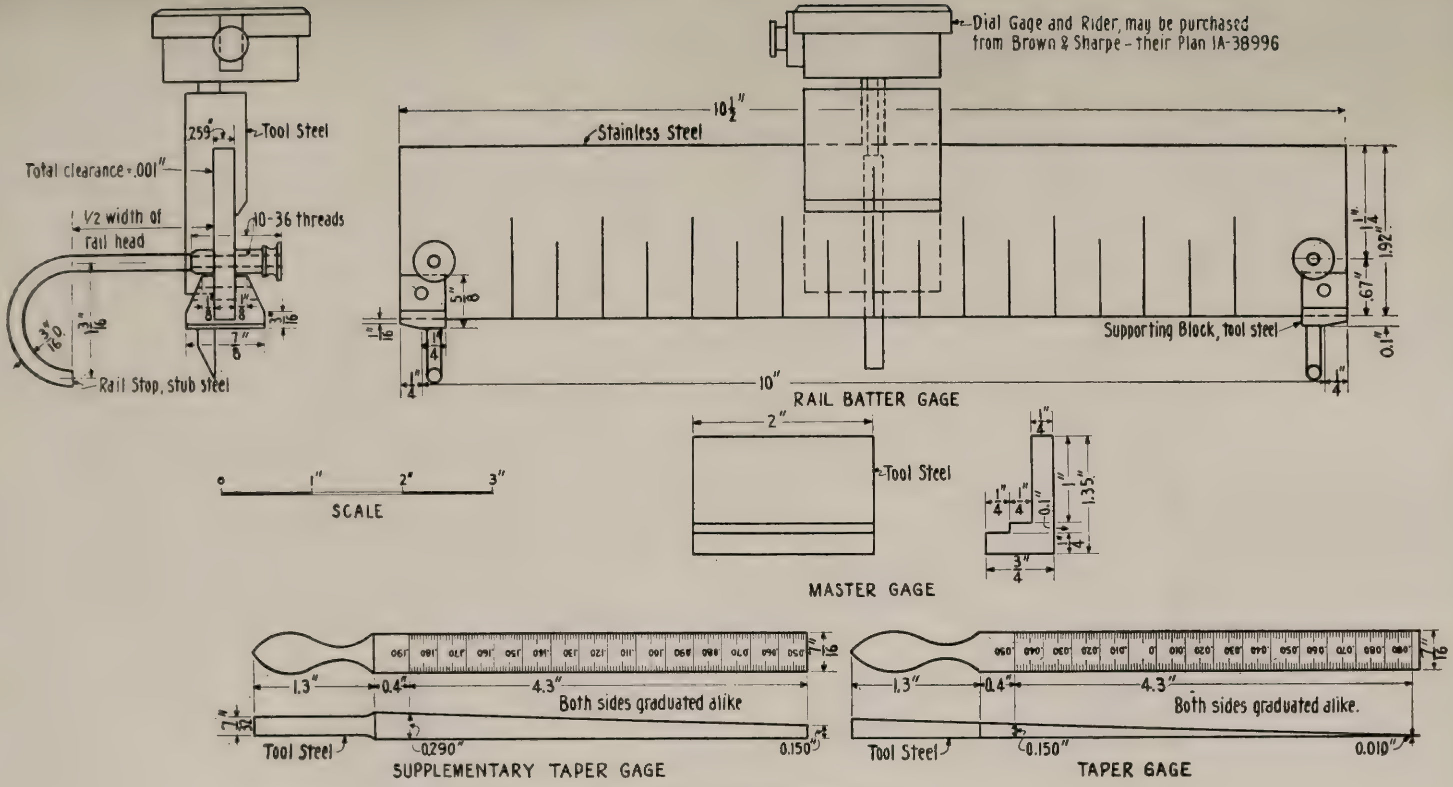


FIG. 5.—Details of 10 Inch Batter Gage.

Fig. 6.—Recommended form for use in reporting notes on batter.

FIELD NOTES FOR TEST OF Sheet of

Test No. Inspection No. Date Trk. No. Location

All Joints Numbered and Measured in Direction of Traffic

Joint No.	Jt. Opening in 16th in.		Batter in Thousandths of inches														Remarks
			Leaving Rail					Receiving Rail									
	Max.	Min.	3″	2″	1″	½″	End	End	½″	1″	2″	3″	4″	5″	6″	7″	

Location E. End of Test

Location W. End of Test

Roadbed Condition

Inspected by Temperature Form No. B-1

FIG. 7.—Recommended form for use in recording summary of batter tests.

SUMMARY OF INSPECTIONS OF TEST NO. Form No. B-2—Batter

Rail Sec. Plan No. of Joint Bar Type of Joint Bar Date Applied

No. Holes in Joint Bar Tie Plates Tie Spacing Location

Inspection		No. Jts.	Deg. Temp.	Joint Openings in 16th in.			Batter in inches														Tie Space in inches	Remarks
							Leaving Rail					Receiving Rail										
No.	Date			Max.	Min.	Diff.	3″	2″	1″	½″	0	0	½″	1″	2″	3″	4″	5″	6″	7″		

Appendix G

(6) RAIL LENGTHS IN EXCESS OF 39 FEET

R. T. Scholes, Chairman, Sub-Committee; W. C. Barnes, J. B. Baker, F. S. Hewes, C. W. Johns, A. A. Miller, J. C. Patterson, G. A. Phillips, H. C. Mann, J. E. Willoughby.

The Committee reports progress on this subject. To determine European practice, which tends towards rails of much greater length than are used in this country, a questionnaire was sent to the railroads of the principal countries of Europe. Answers were received from twenty railroads representing twelve countries.

The rails reported in use are all longer than the standard American practice, as the lengths range from 45-ft. to 98.4-ft. (30 m).

Several countries report welding two to four rails together, forming continuous lengths of from 98.4-ft. (30 m) to as much as 196.8-ft. (60 m). The greatest advance along this line, however, has been in our own country, where continuous stretches of rail have been welded together to an extreme length of over one mile. This was done on the Delaware and Hudson Railroad, which company has been a pioneer in rail welding.

It is quite obvious that economies in track maintenance may be effected by the elimination of the rail joints and in direct ratio to the number of joints eliminated. The ideal condition is to eliminate all joints, which means rails of as long length as practical welded together so as to form in effect a continuous rail. Just how near the ideal may be attained is the problem the Committee will continue to study with the view of offering definite recommendations in next year's report.

The details of the information received through the answers to the questionnaire from the European countries, a description of the Delaware and Hudson and other installations of welded rail, and the use of long rails on American railroads, will be made subject of a monograph that will appear in one of the Summer numbers of the Bulletin.

Appendix H

(7) CAUSE OF THE CORRUGATION OF RAILS

W. C. Barnes, Chairman, Sub-Committee; W. J. Backes, C. B. Bronson, W. A. Duff, F. W. Gardiner, F. M. Graham, J. V. Neubert, W. H. Petersen, G. A. Phillips, R. T. Scholes, W. P. Wiltsee, J. B. Young.

Corrugations in rail first received attention because of their prevalence in tracks of City and Suburban Electric Lines where, because of the type of equipment used, they produced noisy and poor riding track.

Exhaustive tests to determine their cause were undertaken by the American Electric Railway Association, comprehensive reports of which were made at the conventions of that association in 1928, 1929 and 1930.

Their studies included the

(1) Effect of elastic vibrations as effecting variation in pressure between wheel and rail.
(2) Rhythmic variation in rail head hardness.
(3) Rail quality.
(4) Relative hardness of wheel tread and rail.
(5) Chemical characteristics of corrugated rails.
(6) Micrographic studies.
(7) Temperature stresses.
(8) Contact pressures between wheel and rail.

Despite the thoroughness of the tests that were made, only the following very general conclusion was reported at the end of these tests in 1929:

"That rail corrugation is simply the result of overloading the running surfaces of rails with loads that vary more or less periodically in intensity."

The following recommendations for mitigation were also made:

1. Reduction in wheel loads
2. Increasing the wheel contact area
3. Improving the quality of the rail steel

Your Committee reports that corrugation of steam road rails is quite prevalent and occurs in high speed and very low speed track, on tangents and on curves, and with various conditions of ballast and roadbed. In some cases several successive rails are corrugated and in others only single rails or portions of single rails.

The depth of corrugations measured have varied up to a maximum of .008-inch although the greater number of pronounced corrugations are from .003 to .005-inch deep. The distance from crest to crest varies from about 1½ to 8 or even 10 in. with the average about 3 in.

Inspection of corrugated rail in tracks of the Lehigh Valley Railroad indicates that under their traffic and other conditions, corrugations have reached a depth of .003-inch in three to five years after laying of the rail; also that rail laid in 1928 which had become badly corrugated is now apparently in process of being levelled off by traffic. The characteristic bright spots at the crests now appear closer together and in many cases have run together leaving a continuous bright band along the rail head with evidences of the former corrugations extending sideways from said band.

Your Committee has studied this problem at length and is of the opinion that the many variables preclude the determination of a general cause of corrugations. It has not thought it advisable or even practicable without a special appropriation to undertake extensive tests which at best could be expected to determine the cause of corrugations only at a given location, and hence would not lead to a general means of prevention.

Furthermore, your Committee is of the opinion that corrugations are not a serious problem on steam roads, especially since in the rare cases where corrugations are so bad as to seriously affect the riding quality of the track, they can be removed at moderate expense by grinding.

The rail grinding car developed and used by the Lehigh Valley Railroad will satisfactorily remove corrugations at a cost of about $22.00 per mile. This car was described in the technical press in September, 1934.

Your Committee plans to take repeated contours of corrugated rail at identical locations over a period of years to learn more about the apparent self-limitation of growth and automatic smoothing out of the crests. As no report can be made for many years, it is recommended that this subject as an assignment to the Committee be discontinued.

Appendix I

(SPECIAL) JOINT BARS FOR 90-LB. RA–A AND 100-LB. RE RAIL SECTIONS

J. E. Willoughby, Chairman, Sub-Committee; W. C. Barnes, C. T. Dike, F. S. Hewes, W. H. Kirkbride, Wm. Michel, A. A. Miller, E. E. Oviatt, W. H. Petersen, L. Yager.

This subject while not officially assigned for this year has been studied under the assignment made in 1933.

1. The Committee's questionnaire developed:

(a) That 23 railroads have a total of 30,649 track miles of 90-lb. RA–A rail in use. 8 railroads with 7910 track miles of 90-lb. RA–A rail now in use, and 25,825 total miles of track, indicated that there is no present intention of abandoning this rail section.

(b) That 13 railroads have a total of 17,439 track miles of 100-lb. RE rail in use. 7 railroads with a total of 13,196 track miles of 100-lb. RE rail now in use, and 42,606 miles of track, indicated that there is no present intention of abandoning use of the 100-lb. RE rail section.

(c) That the probable future use of these sections will be as follows:

90-lb. RA–A

	Replacement of Lighter Rails	*Track now laid with 90-lb. RA–A which will probably be replaced in kind*	*Total*
Track miles	2,892	2,872	5,764

100 lb. RE

	Replacement of Lighter Rails	*Track now laid with 100-lb. RE which will probably be replaced in kind*	*Total*
Track miles	2,120	9,960	12,080

The replies to the questionnaire which developed the data shown under (c) are not entirely satisfactory for, due to the present unsettled conditions, several respondents expressed uncertainty regarding future rail replacement policies. Therefore the probable future use can reasonably be increased by 25 per cent of the above quantities to cover lines not replying to the questionnaire, replies stating inability to give future rail replacement policies at present time, and short lines which were not canvassed.

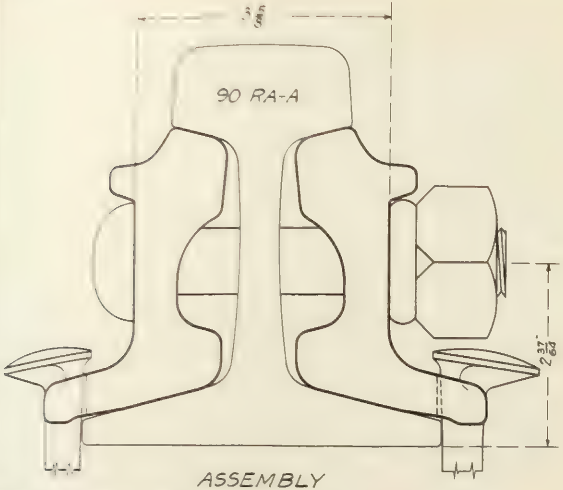
2. Investigation of the properties of joint bars available for use with these rail sections developed that the templets of the same do not best conform to the needs for the joint. Your Committee when preparing the designs of the proposed standard joint bars which are submitted herewith made no attempt to avoid the use of curved lines, angles, or other features of proven merit which appear in the joint bars in current use.

3. The Committee recommends that the following joint bar designs, which are submitted herewith, be adopted and printed in the Manual:

Exhibit A: Head contact—flanged joint bar for 90-lb. RA–A rail.

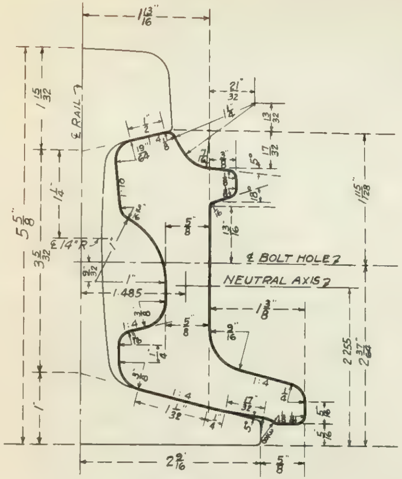
Exhibit B: Head contact—flanged joint bar for 100-lb. RE rail.

Exhibit A

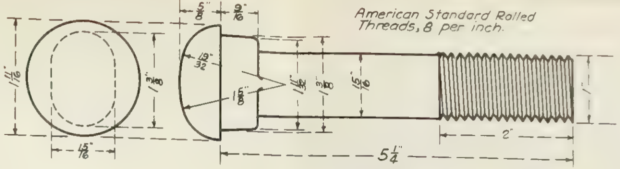


ASSEMBLY

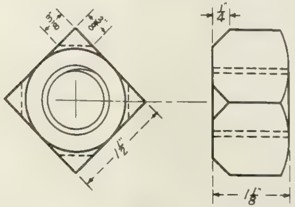
NOTE - Joint bars to be slotted for spikes or not as the practice of the user may require.



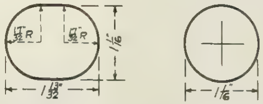
SECTION


American Standard Rolled Threads, 8 per inch.

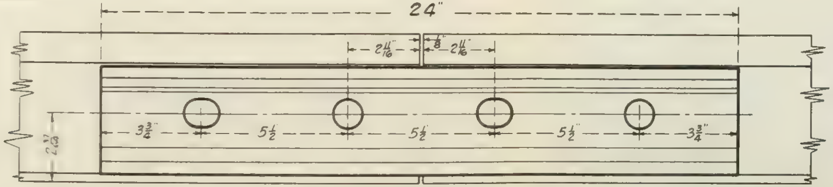
TRACK BOLT



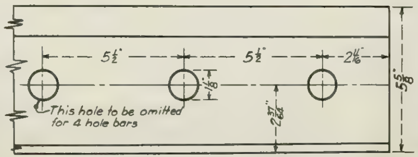
SQUARE NUT



BAR PUNCHING



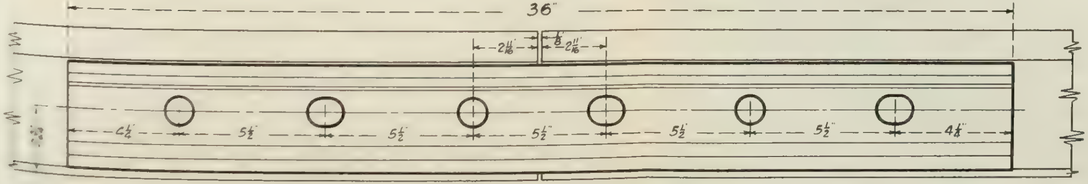
ELEVATION OF 4 HOLE BAR



RAIL DRILLING

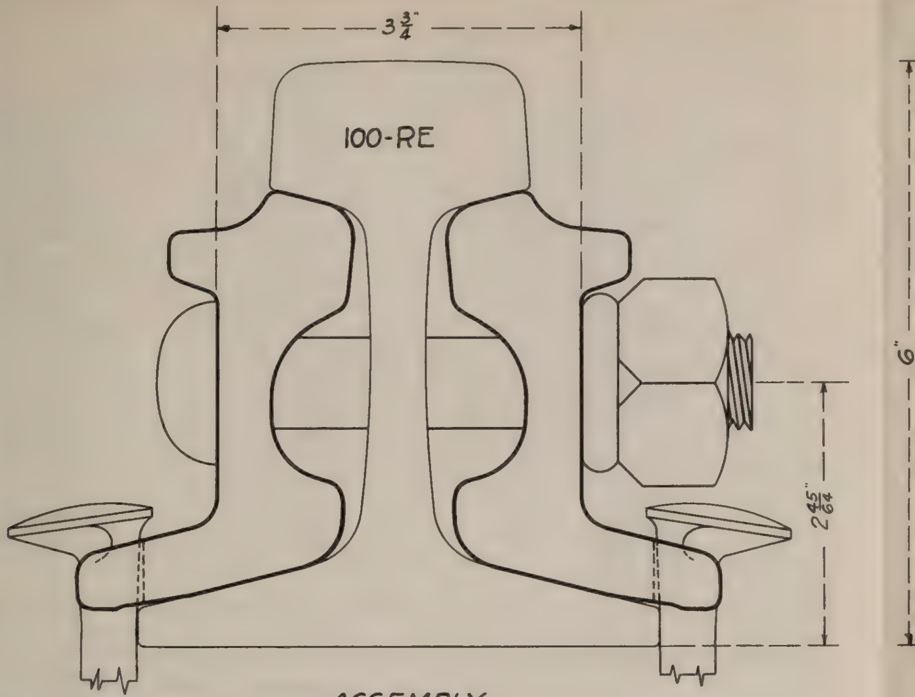
PHYSICAL PROPERTIES		ONE BAR	TWO BARS
Moment of Inertia, In^4		7.33	14.66
Section Modulus	Above N A-In^3	3.39	6.66
	Below NA-In^3	3.78	7.56
Area	Sq. In.	4.69	9.38
Net Weight - 24" Bar,	lbs	31.02	62.04
Net Weight - 36" Bar	lbs	46.53	93.06

Note:- If slotted for spikes, deduct from above 0.09 lbs. per slot.



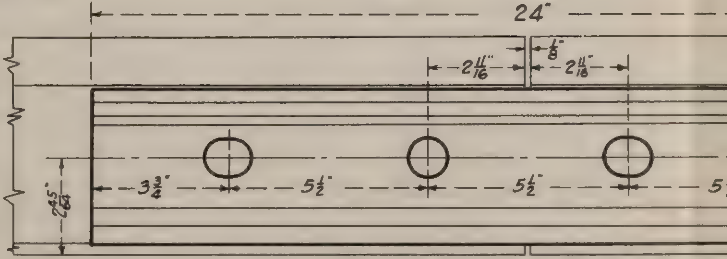
ELEVATION OF 6 HOLE BAR

A. R. E. A.
JOINT BAR AND ASSEMBLY
FOR
90-LB. RA-A. RAIL

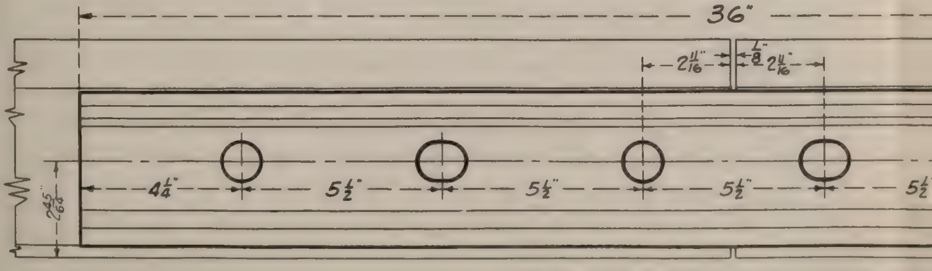


ASSEMBLY

NOTE:- Joint bars to be slotted for spikes, or not, as the practice of the user may require.

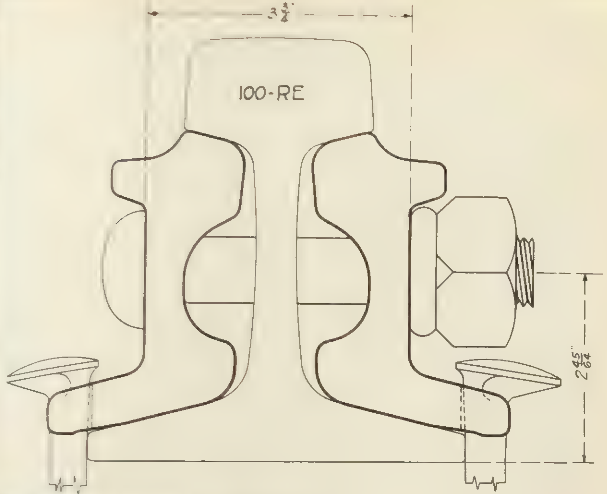


ELEVATION OF 4 HOLE BA



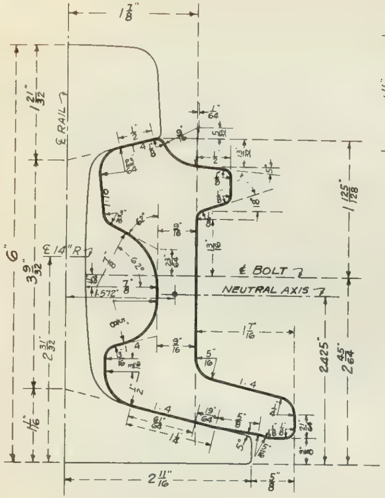
ELEVATION OF 6 HOLE B

Exhibit B

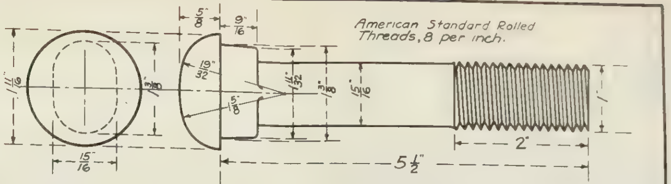


ASSEMBLY

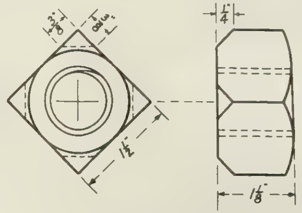
NOTE - Joint bars to be slotted for spikes or not, as the practice of the user may require



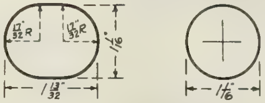
SECTION



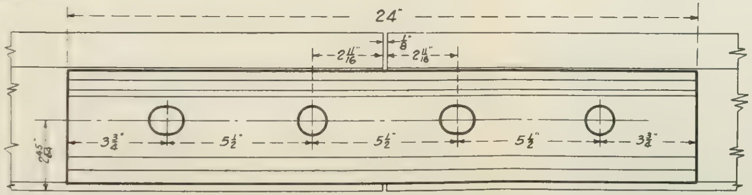
TRACK BOLT



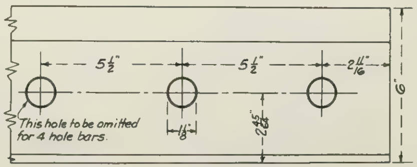
SQUARE NUT



BAR PUNCHING



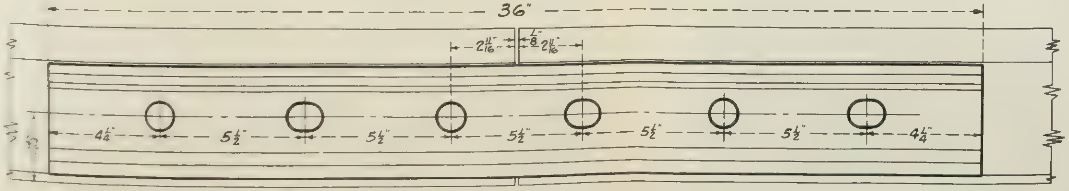
ELEVATION OF 4 HOLE BAR



RAIL DRILLING

PHYSICAL PROPERTIES		ONE BAR	TWO BARS
Moment of Inertia, In.⁴		8.94	17.88
Section Modulus	Above N.A-In³	4.01	8.02
	Below N.A-In³	4.36	8.72
Area Sq. In.		5.04	10.08
Net Weight - 24" Bar, lbs.		*33.47	66.94
Net Weight - 36" Bar lbs.		*50.21	100.42

*Note:- If slotted for spikes, deduct from above 0.09 lbs. per slot.



ELEVATION OF 6 HOLE BAR.

A. R. E. A.

JOINT BAR AND ASSEMBLY
FOR
100 LB. R.E. RAIL

REPORT OF COMMITTEE V—TRACK

C. J. Geyer, *Chairman;*
Lem Adams,
C. A. Alden,
C. W. Baldridge,
W. H. Bettis,
W. H. B. Bevan,
F. J. Bishop,
B. Blowers,
L. H. Bond,
R. W. E. Bowler,
C. W. Breed,
E. W. Caruthers,
H. R. Clarke,
O. U. Cook,
L. W. DesLauriers,
J. J. Desmond,
J. A. Ellis,
H. F. Fifield,
F. W. Gardiner,
F. S. Hales,
C. R. Harding,
O. F. Harting,
N. M. Hench,
F. W. Hillman,
E. T. Howson,
W. G. Hulbert,
T. T. Irving,
F. J. Jerome,
A. A. Johnson,
H. D. Knecht,
J. de N. Macomb,
F. H. Masters,
S. N. Mills,
G. M. Magee,
C. M. McVay,
W. A. Murray,
J. B. Myers,
G. A. Peabody,
S. H. Poore,
J. A. Reed,
W. G. Arn, *Vice-Chairman;*
O. C. Rehfuss,
C. J. Rist,
W. L. Roller,
E. M. T. Ryder,
J. R. Scatterday,
I. H. Schram,
Wm. Shea,
G. J. Slibeck,
G. L. G. Smith,
H. C. Stiff,
G. M. Strachan,
C. R. Strattman,
J. B. Strong,
E. D. Swift,
Hermann von Schrenk,
J. R. Watt,
H. N. West,
J. G. Wishart,
M. J. T. Zeeman,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents reports on the subjects assigned, as follows:

(1) Revision of Manual (Appendix A).

(2) Continuous welding of rail, collaborating with Committees IV—Rail and XXII—Economics of Railway Labor and with the American Transit Association (Appendix B).

(3) Plans and specifications for track tools, collaborating with Committees I—Roadway, II—Ballast, and XXII—Economics of Railway Labor (Appendix C).

(4) Plans for switches, frogs, crossings, slip switches, etc., and track construction in paved streets, collaborating with Committee IX—Highways (Appendix D).

(5) Corrosion of rail and fastenings in tunnels, collaborating with Committee IV—Rail (Appendix E).

(6) Design of tie plates for RE rail sections as developed, collaborating with Committee III—Ties and Committee IV—Rail (Appendix F).

(7) Practicability of using "Reflex" units for switch lamps and targets, collaborating with Committee X—Signals and Interlocking (Appendix G).

(8) Reclamation of serviceable materials from scrap and retired maintenance of way and structures machines, tools and appliances, collaborating with Committee XXVII—Maintenance of Way Work Equipment and with the Joint Committee on Reclamation (Appendix H).

(9) Determination of the limiting relative positions of the abutting rails of fixed and drawspans of bridges and proper tolerances, collaborating with Committees X—Signals and Interlocking, XV—Iron and Steel Structures, and with the Signal Section (Appendix I).

Bulletin 383, January, 1936.

Action Recommended

(1) That revisions recommended in Appendix A be approved for publication in the Manual.

(2) That report in Appendix B be received as information.

(3) That Plan 12–A, dated 1936, covering a carpenter's adze, shown in Appendix C, be adopted as recommended practice and published in the Manual; that Plan 26 for a scoop shovel be received as information; and that conversion graph for hardness test be received as information.

(4) That Plan 920 showing lengths of angles and radii for curved switches in Appendix D be adopted as recommended practice and published in the Manual.

(5) That tie plate plans K, L, M, N, O, and P appended in Appendix F be adopted as recommended practice and published in the Manual.

(6) That progress reports in Appendices E, G, H, and I be received and the subjects continued.

THE COMMITTEE ON TRACK,
C. J. GEYER, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

W. G. Arn, Chairman, Sub-Committee; W. H. B. Bevan, C. W. Breed, J. A. Ellis, F. S. Hales, C. R. Harding, F. W. Hillman, E. T. Howson, A. A. Johnson, S. N. Mills, C. M. McVay, J. B. Myers, I. H. Schram, William Shea, G. L. G. Smith, J. R. Watt, J. G. Wishart, M. J. T. Zeeman.

The Committee recommends:

That there be two groups of definitions—one for the Manual, and one for the trackwork portfolio. That all definitions included in the Manual itself be segregated into a chapter on definitions in alphabetical order at the back of the book. That those definitions referring particularly to trackwork portfolio plans be printed in the portfolio only.

That the following changes be made:

Insert as the first paragraph in chapter:

> "The AREA Portfolio of Trackwork Plans, Specifications, and Definitions, although a separate volume, is a part of this Manual."

DEFINITIONS

Omitting the following definitions:

Alinement, Branch Line, Closure Rails.

Change the definitions of following terms as shown:

Crossing (Track).—A structure used where one track crosses another track at grade and consisting of four connected frogs.

Crossover, Double, or Scissors.—Two crossovers which intersect between the connected tracks.

Elevation (of Curves) (Superelevation).—The vertical distance that the outer rail is above the inner rail.

Foot Guard.—A filler for the space between converging rails to minimize the possibility of a person's foot becoming caught.

Gage Line.—A line ⅝-in. below the top of the center line of head of running rail or corresponding location of tread portion of other track structures along that side which is nearer the center of the track.

Gage (of Track).—The distance between the gage lines, measured at right angles thereto. (The standard gage is 4 ft.-8½ in.)

Gage (Track Tool).—A device by which the gage of a track is measured, checked or determined.

Guard Rail.—A rail or other structure laid parallel with the running rails of a track to prevent wheels from being derailed; or to hold wheels in correct alinement to prevent their flanges from striking the points of turnout or crossing frogs or the points of switches. (See Guard Rail Terms.)

A rail or other structure laid parallel with the running rails of a track to keep derailed wheels adjacent to running rails.

Joint Bar.—(Use Rail Committee's definition).

Joint Drilling.—(Use Rail Committee's definition).

Spot Board.—A sighting board placed above and across the track at the proposed height to indicate the new surface and insure its uniformity.

Surface (Track).—The condition of the track as to vertical evenness or smoothness.

Switch.—A track structure used to divert rolling stock from one track to another.

Tie Plate.—A plate interposed between a rail or other track structure and a tie. (See Portfolio for special forms of plates.)

Turnout.—An arrangement of a switch and a frog with closure rails, by means of which rolling stock may be diverted from one track to another. (For Turnout Terms see Portfolio.)

Wye.—A track with two connecting tracks arranged like the letter "Y," by means of which rolling stock may be turned.

MAINTENANCE OF LINE

(a) Tangents.—Tangents should be adjusted between summits, between curves, or between a curve and a summit. Track centers should be set with transit.

(b) Curves; Use of Easement Curves (Spirals).—Easement curves should be used with all curves with an elevation of two inches or more. When elevation is less than two inches, the use of easement curves should be a matter of judgment considering the amount of offset, speed and other features.

Length of easement curves should be based on the maximum allowable speed and should not be less in length than that which will cause a rise of not more than 1½ inches per second for the maximum speed. If physical conditions permit the length of easement curve should be based on a rise of not more than 1¼ inches per second.

Curve elevations should be run out uniformly over the easement curve.

If no easement curve is provided the elevation should be run out on the tangent, using the full elevation at point of curve.

Easement curves should be used between curves of different degrees and change of elevation should be effected just as between curves and tangents.

Any form of easement curve is satisfactory which is of the general form of a cubic parabola.

(Retain the graph and text on page 203, except Paragraph 3.)

SPIRALS

Notation

(Retain the matter on pp. 204 to 213, and at the bottom of the table on page 213, add: "Additional tables up to 45 degrees may be found in the 1929 Manual, pp. 214 to 227.)"

MAINTENANCE OF SURFACE

(a) Elevation of Curves

The approximate formula:

$$e = \frac{Gv^2}{32.16\,R}$$

in which

e = Elevation in feet,
G = Gage of track in feet,
v = Velocity in feet per second,
R = Radius of curve in feet,

will give essentially correct theoretical elevation for the outer rail of curves.

From the above may be derived the simpler formula,

$$E = .00066\,DS^2$$

in which

$E =$ Elevation in inches of the outer rail at the gage line,
$D =$ Degree of curve,
$S =$ Speed in miles per hour,

and from this the approximate formula:

$$E = .00066\,DS^2 - 3,$$

will give 3-inch unbalanced speed elevations for the outer rail of curves, in which the resultant of forces passes practically six inches beyond the center line of track, where center of gravity is 84 in. above rail, with an allowance of 1½-in. for horizontal play in equipment.

The following table gives the speeds in miles per hour in multiples of 5 (which is the general practice for use on speed-limit signs) for equilibrium and three-inch unbalanced elevations.

(c) Proper Method of Tamping

(1) "Dirt" (instead of "Earth or Clay") Ballast.

Method.—Tamp solidly from end of tie to rail, and then preferably allow a train to pass over. Tamp from rail to a point 18 inches inside; tamp center of ties loosely with the blade of the shovel; the dirt or clay between the ties should be placed in layers and firmly packed with feet or otherwise, so that it will quickly shed the water; the earth should not be banked above the bottom of the ends of the ties; the filling between the ties should not touch the rail and should be as high as, or higher than, the top of the ties in the middle of the track.

(2) No change.
(3) Burnt Clay Ballast. (Omit)
(4) Broken Stone or Slag.

Tools—Shovel, tamping pick, ballast fork or tamping machine.

MAINTENANCE OF GAGE

(a) Appliances and Methods Used to Prevent Spreading of Track and Canting Rails on Curves.

1. Tie plates with shoulders are recommended on all treated ties, on all curves and in all other cases where economy in maintenance justifies.

2. Where tie plates are not used, the outside of both rails on curves should be double-spiked.

(b) General

1. The gage (tool) should be the standard gage.
2. No change.
3. No change.
4. No change.
5. No change.
6. No change.
7. The use of gage rods is recommended on curves where it is difficult to maintain gage. (New)

ANTI-CREEPERS

The use of Anti-creepers to prevent longitudinal movement of rail in track is recommended.

A

SPEED TABLE FOR CURVES

MAXIMUM SPEED IN MILES PER HOUR RECOMMENDED AS GOOD PRACTICE (NOT LIMITS OF SAFETY) WHERE CENTER OF GRAVITY IS 84 INCHES ABOVE THE TOP OF RAIL

E = Speed at Equilibrium Elevation

M = Maximum Speed = Speed at 3" Unbalanced Elevation

DEGREE OF CURVE	ELEVATION OF OUTER RAIL →	$\frac{1}{4}$"	$\frac{1}{2}$"	$\frac{3}{4}$"	1"	$1\frac{1}{4}$"	$1\frac{1}{2}$"	$1\frac{3}{4}$"	2"	$2\frac{1}{4}$"	$2\frac{1}{2}$"	$2\frac{3}{4}$"	3"	$3\frac{1}{4}$"	$3\frac{1}{2}$"	$3\frac{3}{4}$"	4"	$4\frac{1}{4}$"	$4\frac{1}{2}$"	$4\frac{3}{4}$"	5"	$5\frac{1}{4}$"	$5\frac{1}{2}$"	$5\frac{3}{4}$"	6"	$6\frac{1}{4}$"	$6\frac{1}{2}$"	$6\frac{3}{4}$"	7"	← ELEVATION OF OUTER RAIL	DEGREE OF CURVE
0°30'	E	30	40	50	55	60	65	70	75	80	85	90	95	100		105	110													E	0°30'
	M	100		105	110																									M	
1°00'	E	20	25	35		40	45	50	55		60	65		70		75		80		85			90		95			100		E	1°00'
	M	70		75		80		85			90		95			100		105			110									M	
1°30'	E			25	30	35		40	45		50		55			60		65			70			75			80			E	1°30'
	M	35		60		65			70			75			80			85			90				95				100	M	
2°00'	E		20		25	30		35		40		45		50			55			60			65				70			E	2°00'
	M	50			55			60			65				70				75				80				85			M	
2°30'	E						30			35		40			45			50			55				60					E	2°30'
	M	45				50			55				60				65					70								M	
3°00'	E			20		25		30			35			40			45				50				55					E	3°00'
	M	40			45				50				55					60					65					70		M	
3°30'	E						25			30			35			40				45				50						E	3°30'
	M			40				45					50				55							60						M	
4°00'	E				20			25			30			35				40					45					50		E	4°00'
	M	35				40					45					50					55						60			M	
4°30'	E											30				35				40					45					E	4°30'
	M			35				40						45					60						55					M	
5°00'	E					20			25				30				35					40						45		E	5°00'
	M				35					40						45						50							55	M	
5°30'	E						20			25				30					35					40						E	5°30'
	M						35						40						45						50					M	
6°00'	E							20			25				30						35					40				E	6°00'
	M	30							35						40						45								50	M	
7°00'	E								20				25					30						35						E	7°00'
	M					30						35							40								45			M	
8°00'	E									20				25						30							35			E	8°00'
	M	25						30							35								40							M	
9°00'	E										20					25							30							E	9°00'
	M			25							30							35									40			M	
10°00'	E											20						25							30					E	10°00'
	M					25							30									35								M	
11°00'	E												20						25								30			E	11°00'
	M						25								30										35					M	
12°00'	E												20								25									E	12°00'
	M	20							25									30										35		M	

Since the elevation required is a function of the train speed, this speed is the first element to be determined.

In general, in determining speed for which a curve shall be elevated, it is necessary to consider the different speeds at which various classes of trains operate. Where conditions do not warrant greater speeds, equilibrium speeds should be used.

It is recommended that for good riding conditions on passenger trains and minimum wear on rail and equipment, the speeds be kept within the limits shown in this table The limits as shown will also serve for use on any lower height center of gravity, as the speeds for 3" unbalanced elevation for 84" height center of gravity are approximately the same as for $2\frac{1}{4}$" unbalanced elevations for 54" center of gravity.

For traffic at one speed equilibrium elevation is the most economical.

Where both fast and slow trains are operated on the same track it is advisable to increase the speed limit of fast trains above those shown for equilibrium speed.

For a preponderance of slow traffic where schedules make it necessary and conditions of track permit, speeds up to the maximum shown may be used.

It will be noted that for the sharper curves there is little difference in the number of miles per hour that may be run at each of the various superelevations.

SPEEDS OF TRAINS THROUGH CURVES AND TURNOUTS

(That pending further study and revision the text and table on page 231 and the graphs on pp. 232 and 233 be omitted.)

INDEX TO TRACKWORK PLANS

(That this text be omitted, as this index is shown in Trackwork Portfolio.)

SPECIFICATIONS FOR FROG FILLER SECTIONS

(That these specifications be omitted and that they be included in the Trackwork Portfolio.)

SPECIFICATIONS FOR RELAYER RAIL FOR VARIOUS USES

Resawing Rails. (Omit)

RESAWING AND RECONDITIONING OF RAILS FOR RELAYING, AND BUILDING UP OF BATTERED RAIL ENDS IN TRACK.

(Omit)

Inclusion in the Manual:

BUILDING UP OF RAIL ENDS IN TRACK

The reconditioning of rail ends, frogs, switches, crossings and joint bars is recommended as good practice.

SPECIFICATIONS FOR MALLEABLE IRON TIE PLATES

(Omit) Seldom used.

ANTI-CREEPERS

(Omit).

SPECIFICATIONS FOR STEEL SCREW TRACK SPIKES

(Omit text on pp. 255 and 256, and designs on pp. 257 and 258.)

OILING TRACK FIXTURES

The following is recommended as good practice:

(1) Oil track bolts, joint bars and turnout fixtures.

(2) Oil rail, tie plates and spikes when subjected to special corrosive conditions when ultimate life is affected.

(3) Oiling of rail, tie plates and spikes to be done by machine; other materials by brush; new track bolts and joints to be oiled before applying.

(4) Satisfactory oil for this purpose should conform to the following general specifications:

Asphalt Base Dipping Oil Specifications

Flash point, minimum	130 degrees Fahr.
Asphalt, 100 penetration, minimum	45 per cent
Viscosity, Saybolt Universal, 130 degrees Fahr.	240–350 seconds

SPECIFICATIONS FOR THE LAYING OF NEW TRACK

(Insert) "Specifications for the Laying of New Track may be found in 1929 Manual, pp. 259 to 262."

In Supplement to the Manual of 1929, Bulletin Vol. 36, Numbers 367–368, July–August, 1934, pages 21 and 27 to 39, inclusive, are shown Index Sheet Plan A and Plans 1 to 22, inclusive, and plan 25, covering plans for Track Tools and Track Tool Handles. On pages 22 to 27, inclusive, are shown Plan B, C–1, C–2, D–1, D–2, D–3, E and F, covering specifications for track tools and track tool handles.

These plans have been redrawn, revised and rearranged as to numbering in collaboration with tool manufacturers and Committees on Roadway, Ballast and Economics of Railway Labor.

Committee recommends that material on pages 21 and 27 to 39, inclusive, be withdrawn and sheet showing Table of Contents, together with Plans 1, 2, 3, 4, 4A, 5, 6, 7, 8, 9, 10, 11, 11A, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 and 25, as revised and dated March, 1936, be substituted therefor.

Also, that material on pages 22 to 27 be withdrawn and sheets marked Appendix A, pages 1 to 9, inclusive, be substituted therefor.

Appendix B

(2) CONTINUOUS WELDING OF RAIL

H. F. Fifield, Chairman, Sub-Committee; Lem Adams, C. W. Baldridge, F. J. Bishop, F. W. Gardiner, F. S. Hales, N. M. Hench, E. T. Howson, G. M. Magee, W. A. Murray, J. B. Myers, J. A. Reed, Jr., J. R. Watt, G. J. Slibeck, A. N. Talbot, J. Wolfe.

The assignment of the subject "Continuous Welding of Rail" to Sub-Committee 2 is an original assignment and it is the sense of the Committee that the following report should cover briefly the history of continuous welding of rail in trolley construction, foreign steam roads and finally, the recent development on steam roads in the United States.

It is of course understood that insofar as the subject of continuous welding of rail in the steam roads of this country is concerned it is in its infancy and that anything included in this Committee's write-up is simply to be accepted as a progress report.

A questionnaire has been issued and is attached hereto covering continuous welding of rail by the Oxweld method on three railroads, by the Thermit method on one trolley road and by the Thermit and Flash Weld method on the D.&H.R.R. as well as the Thermit method on the Bessemer & Lake Erie R.R. Insofar as this Committee has been able to determine, information given in the questionnaire covers all the continuous welded track in steam roads in this country of open construction of any length beyond a few rails which have been welded in crossings, station platforms and retarders.

Continuous welding of rail has been standard practice on the various trolley roads in this country for a good many years, various methods having been used, the principal one being the insert Thermit Weld.

In addition to track shown in questionnaire on the Chicago Surface Lines at Vincennes Avenue there are many other pieces of open track in this country, some of them equipped with expansion joints of various types and a great many of them not so equipped, Cleveland Railway Company having a rather extensive section on Mayfield Road, Cleveland and Kansas City Public Service Company having a considerable amount of old 70-lb. ASCE rail in their country club line. At the latter location there are no

REPLIES TO QUESTIONNAIRE ON CONTINUOUS WELDING OF RAIL

Railroad	Boston & Maine	Central of Georgia	Clinchfield R. R. Co.	Chicago Surface Lines	Delaware & Hudson R. R.	Delaware & Hudson R. R.	Delaware & Hudson R. R.	Bessemer & Lake Erie
Location welded section	Hoosac Tunnel—No. Adams, Mass.	Between Columbus and Birmingham, Ala.	Clinch Mountain Tunnel, Spears Valley, Va.	Vincennes Ave. 90 to 95th St., Chicago	Albany, N. Y.	Mechanicville, N. Y.	Schenectady, N. Y.	Just north of River Valley Station, Pa.
Continuous length welded track	17600 ft. E. B. 7100 ft. W. B. See Text	2457 ft.	4095 ft.	3902 ft. N. B. 3910 ft. S. B.	2994 ft. E. B. 2661 ft. W. B.	2517 ft. S. B. 2519 ft. N. B.	11,787 ft.	1 Mile S. B.
Date installed	Feb.-Mar. 1930	Sept. 1930	March 1932	1928	Aug.-Sept. 1933	May 1934	June-Sept. 1935	Oct.-Nov. 1935
Straight-Curve or both	Straight	64 ft. on curve balance straight	Straight	Straight	Both	Straight	Both	Both—1800′ Straight 2000′ on 1°-30′ 1500′ on 5°
Maximum degree curvature		6°			7°-30′		4°	5°
Grade	.5%	1.3%	.2%	App. level	1.0%	.3%	.7%	App. ½ level and ½ on 0.65 grade
Length of rail	39 ft.	39 ft.	39 ft.	62 ft.	39 ft.	39 ft.	39 ft.	39 ft.
Weight of rail	100 lb. N. H.	90 lb.	100 lb. ARA—B	100 lb.—I. S. Co. 10025—6″ high.	130 lb.	131 lb. RE	131 lb.	131 lb. RE
Total joints welded both sides	1231	126	209	240	318	254	621	269
Type of weld	Oxweld V type See Text	Oxweld V type See Text	Oxweld V type See Text	Thermit head insert See Text	Thermit pressure weld See Text	Thermit pressure weld See Text	551 Thermit pressure weld 70 electric flash weld See Text	Thermit pressure weld
Type of track Give type of fittings, kind of ties, depth, kind and condition of ballast, etc.	Neafie bars with base plates, rail anchors double shoulder tie plates, hardwood treated and untreated ties, gravel ballast—full section 6 to 12″ deep, 21 ties to a 31 ft. rail. Cut spikes.	100% contact angle bars. Tie plates 10″ x 7½″, 24 ties to rail length mostly untreated oak.	7″ x 11″ single shoulder tie plates, oak ties, dirty stone ballast.	½″ shoulder tie plates with rail clips and ⅞″ x 6″ screw spikes, 6″ x 8″ x 7′ treated red oak ties. Crushed slag ballast.	Regular M & L track construction. See Text.	Regular M & L track construction. See Text.	Regular M & L track construction. See Text.	GEO construction, treated red oak ties 7″x9″x8′-6″ 22″ centers on ash sub-ballast and 1 foot of crushed stone top ballast. 6¾″x14 21/32″ tie plates 27/32″ maximum thickness, 4 screw spikes per plate. All new track construction throughout.
Cost of weld in place.	$5.91	App. $4.30	$6.95	$7.10	$19.53	$19.12	Thermit $12.00 App. Flash $9.00 App.	
Equipment and organization	10 Welders—4 helpers, 1 Foreman—5 Oxweld Instructors. Regular railend welding equipment.	2 Welders—2 Helpers Engine & Section Crew to drag strings of rail in place.	2 Welders—2 Helpers 2 Oxweld Instructors assisted by Laborers	1 Thermit Welding Operator. 7 Laborers—1 grinding operator—2 Helpers. Usual Thermit welding equipment.	1 Welder—1 Asst. Welder 1 Acetylene Welder 1 Molder—9 others. Usual Thermit welding equipment. See Text.	1 Welder—1 Asst. Welder 1 Acetylene Welder—1 Molder—9 others. Usual Thermit welding equipment. Railends milled at steel plant. See Text.	1 Welder—1 Asst. Welder 1 Acetylene Welder—1 Molder—9 others. Usual Thermit welding equipment. See Text.	1 Welder—1 Asst. Welder 1 Acetylene Welder—1 Molder—9 others Usual Thermit welding equipment. See Text.
Work done by RR. Contractor or both	Railroad	Railroad	Railroad	Railroad	Railroad under Contractor's supervision	Railroad under Contractor's supervision	Railroad under Contractor's supervision	Railroad under Contractor's supervision
Were bars applied after welding	Yes	Yes	Yes	No	No	No	No	No
Maximum speed allowable	30 Miles per Hr.	30 Miles per Hr.	None specified.		20 Miles per Hr.	35 Miles per Hour	No restriction	Passenger trains-55 mi. per hr. Freight trains-35 mi. per hr.
Approximate annual tonnage	12,775,000 Gr. T.	5,110,000 tons exclusive of locomotives and 5 passenger trains daily	4,000,000		12,104,000 ton N. B. 4,285,000 tons S. B.	3,000,000 N. B. 2,800,000 S. B.	9,000,000	Approximately 9,000,000 tons
Passenger-Freight or both	Both	Both	Both	Street railway cars and Service Equipment	Both	Both	Freight only	Both
In tunnel or open	All in tunnel	All in tunnel	All in tunnel	Open	Open	Open	Open	Open
Approximate annual range of temperature	30° Central Shaft 110° Portals	75°	70°	128°	125°	125°	125°	110° (Extreme of 100°—Min.-20°)
How anchored	9 anchors per 39 ft. rail	4 anchors per 30 ft. rail	Not anchored	See type of track	See type of track	See type of track	See type of track	No anchors
Provision for expansion either end of section	None	¼″ at each end. Not needed.	None	Expansion joints used, 12 in number spaced about even thru the welded section.	None	None	None	No special provision, four standard joint bars, 2 at each end
Did rail creep, if so, approximate amount.	EB at Portal, 11 weeks after laying, ¾″ north rail. None on south rail	No	No	No	No	No	No	No—just completed
Any cuts necessary account of expansion	No	No	No	No	No	No	No	No—just completed
Number or percentage failures to date	308 Failures—25% 5 years' service	4 failures due to welds cracking out where rails were damaged by heat	5 failures, probably due to improper tamping under joint ties	None	2%	None	None	None—just completed
Were welded joints true, or defective in line or surface	Some joints defective in surface	Welded joints reasonably true	True	True	True	True	True	True
Approximate annual saving in track maintenance	$1500 per year—labor.	Expect to double the life of rail. Before welding relaid every 3 years.	$500		See Text	See Text	See Text	
Maximum wheel load	34,950 lb.	26,250 lb.	30,000 lb.	12,500 lb.	26,800 lb.	40,000 lb.	40,000 lb.	37,900 lb.
Atmospheric temperature when rail laid	45° F.	45°	35°	30° to 65°	75°	70°	78°	65°
Temperature of rail	53° F.	45°	35°	30° to 65°	No record	No record	No record	

tie plates and the rails are fastened to the ties with cut spikes. The Chicago Surface Lines have a mile or two of track welded in 700 or 800-ft. lengths on private right-of-way south of 63rd Street, running from Clearing to Argo, Ill. This track is 100-lb. rail with fair ties and of rather light construction. The Department of Street Railways, Detroit, have some track which is open construction on Woodward Avenue in Detroit and there is a similar installation of two or three miles of track in Gary, Ind. In both of these cases the track is laid in the middle of the street and is of open construction. In Gary the rail was light and very old when welded. There is also an installation of Thermit welded track on the Boston Subway and one on the Philadelphia Rapid Transit Company.

It has been the practice to weld rail in foreign countries particularly Germany for six or seven years. In the case of the German railroads a certain proportion of the construction is of the GEO type but a great deal of it is for less rigid construction. The German Thermit Company take the position backed by a considerable amount of experience that in general rails can be welded in lengths up to 30 meters in any type of construction. Where the rail length is to be greater than 30 meters they usually raise the question of the type of construction. A more recent development in Germany has been the flash weld as done by the A.E.G. flash welding machines. These machines are built to weld rails alongside but not in the track. The standard practice with the GEO and similar construction is to weld in lengths of 60 to 90 meters and in some cases the German Federated Railroads have installations where rails have been welded in 120 meter lengths. Recently the German Federated Railroads welded rails one kilometer in length and in this continuous welding three types of track construction were installed. One part of the kilometer length is GEO construction; a second is a type deviating slightly from that, and a third is a wedge construction, such as the standard track construction in Belgium. This installation was not only to try out welding in long lengths but also as a test of the different types of track construction.

A brief summary of the work done in the various countries outside of the U.S. is as follows:—

GERMANY—Thermit and flash welds extensively used. Up to the present date there have been over 1500 miles of track welded by these two methods, approximately two-thirds of this done by the Thermit although the proportion of flash welds has increased greatly during the past two years. Flash welds made by the A.E.G. Flash Welding Machines.

HUNGARY—Considerable work has been done by the Thermit and flash welds methods and by the Katona Joint which is a patented type of electric-arc bar weld. In Hungary the rails are welded together in lengths of 100 to 270 meters and joined by a patented expansion or slip joint called the "Csillery". Total as of last year up to close to 200 miles of track had been done by the above method.

FRANCE—Both Thermit and flash welds are now being used. Practice is to weld into rail lengths up to 100 meters, and they are experimenting with greater lengths using expansion joints between the long rails.

EGYPT—In addition to continuous stretch of Thermit welded track 1 kilometer has been laid with rails 36 meters long which were made from three 12 meter rails flash welded in Germany.

ITALY—Most of the welding consists of 2—18 meter rails with the heads arc-welded and using angle bars. One installation of Thermit welded rail has been made in a tunnel.

POLAND—200 meter stretch of arc-welded rail has been installed in slow speed track in Warsaw Terminal.

SWEDEN—Experimental work is being carried out in Sweden on welded rails. An A.E.G. flash welding machine is being used for this work.

SWITZERLAND—Considerable welding research is being carried out in Switzerland. Electric arc, flash and oxy-acetylene methods are being used to weld two rails together.

AUSTRALIA—The Victorian Railways have salvaged a great deal of old rail by welding it into lengths of 200 to 250 feet and are so satisfied they are now welding rails on both their electrified suburban lines and main lines. Practically all of this work is being done by the Thermit process.

In a similar manner the New South Wales Railway Commission are doing the same thing on a larger scale, there being about 60,000 welded joints in the lines of the latter road. In addition to this the rails in a tunnel were continuously welded giving a length of 5,760 feet.

Other countries—including Belgium, Holland, Austria, Finland, Czecho-Slovakia and Yugoslavia—are working on welding rail experimentally, but insufficient data is on hand in these cases, to make a separate report worth while.

The situation as to continuous welding of rail in open track on steam roads in this country is outlined in the information given by the various roads in the attached questionnaire.

On the lengths given in the answers to Question 3 the installation of an insulated joint without any provision being made for expansion is not considered a break.

On the Boston and Maine the rail was installed in the Hoosac Tunnel, which is approximately 4¾ miles long. On the eastbound track the installation starts 17,600-ft. from the east end of the tunnel and continues to the east portal. On the westbound, installation started at the central shaft and runs west.

THE "VEE" TYPE BUTT WELD.—The railends are "Vee-ed" or bevelled, using an oxy-acetylene flame, on head and web and base with a cutting torch to allow welders space to work in when the two rails are butted together. After rails are placed end to end and alinement checked, the ends are raised to allow for the difference in contraction when the rail cools between the head and the base due to the difference in section. Using Oxweld No. 1 rod the operator welds both sides of the base up to the web and about one-half of the head. The head is completed with the harder Oxweld MW rod and all surfaces of the weld smoothed with a flatter. The welds were made outside of the tunnel in lengths of seven or eight rails on stands after which the rails were skidded onto flat cars and unloaded in the tunnel, pulling the rails over the end of car in the trough of a steel beam. Closure welds were made in the tunnel as the rail was laid. Although the percentage of failures is rather large it should be considered that the welding was done before welding of this type had been perfected. It is felt that regardless of the number of failures the welding of rail in this tunnel has resulted in considerable saving both in maintenance and increase in life of the rail. It should be noted that track is more or less standard on a great many railroads throughout the country and it is not of the heavier so-called permanent track as the M&L used on the D&H and the GEO used on the Bessemer & Lake Erie. The same type of weld was made on both the Central of Georgia and the Clinchfield R.R. as shown on questionnaire.

The Thermit pressure weld which was used in most of the work on the D&H is a Thermit fusion weld on the base and about one-half way up the web, the rest of the web and the head being a pressure weld. To effect this combination weld the ends of the rails to be joined are cut on a bevel from the top backward into the rail a distance of one-sixteenth of an inch at the base. Furthermore the lower half of the web and the entire base of each rail are cut back about ¼-in. with an oxy-acetylene torch to provide ample space for the entrance and fusion of the Thermit metal with the rail metal. The rails are first clamped together with the ends slightly raised to obtain proper line and surface. They are then preheated with gasoline burners and when temperature of from 1500 to 1700 degrees Fahr. is reached the Thermit which consists mainly of iron-oxide and aluminum is ignited. In about 20 seconds a temperature of 5000 to 5500 degrees Fahr. being reached the molten metal is poured in a mold which has been clamped around the rail ends prior to the preheating. This metal is sufficient to fill the mold to about one-half way up the web and the slag which results from the reaction fills the remainder of the mold over the top of the rail. The metal around the base and web melts the rail so that the whole becomes a molten mass. The slag around the head of the rail and upper part of the web raises it to a welding temperature of 2400 degrees in about 3 minutes at which time the rail ends are pulled together approximately ¼-in. forming the pressure part of the weld. As it cools it results in a solid unit at the junction of the rails or the Thermit weld. Following the heating operation the joint is ground with a grinding machine to bring the head of the rail at the point which has been upset by the pressure weld to the line and surface at each side of the joints.

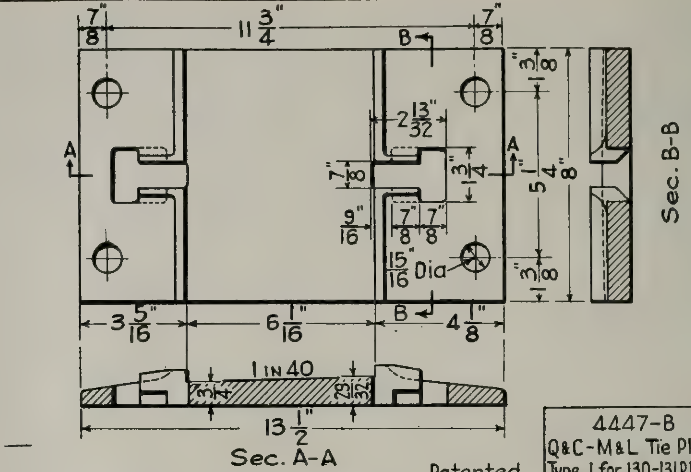
FLASH WELD.—This is a method of butt welding by continuous arcing between ends of the parts to be joined. The two ends of the rails are clamped in the welding machine. One of the clamps is movable, and both clamps are connected to the terminals of a low voltage transformer. No particular preparation of the faces is needed, although reasonably parallel surfaces expedite the operation. No flux is used. The metal is volatilized by the arc, and a pressure of gas is built up between the surfaces during the arcing, this pressure preventing access of air to the faces. Therefore there is no oxidation, and the faces are kept chemically clean. The pressure of gas blows all molten metal out of the gap, and at the proper time—about two minutes after starting of the arcing—the faces are brought together under heavy pressure. This squeezes out all metal that is molten, and the weld is made. It is, in fact, a hot work weld. Only a trace of cast metal remains in the joint.

The flash welds made for the D&H were made by the General Electric Company at their Schenectady plant which was within two miles of the point where the rails were laid. These welds were made on a machine which was not designed to weld rail but which the General Electric Company had used for welding other large shapes. Rails were welded in stretches of three rails after which they were laid in the track and joined with the Thermit weld.

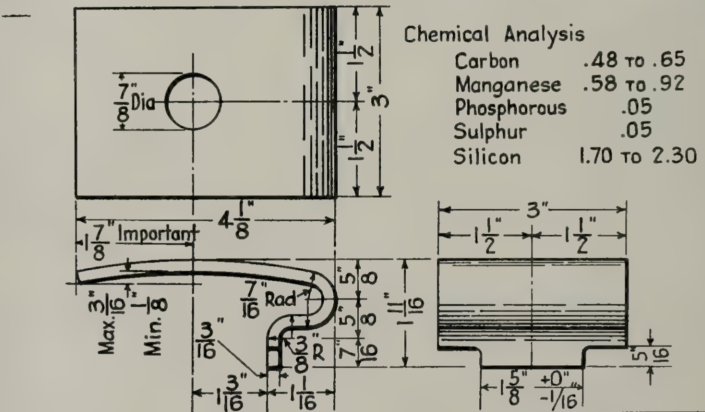
Tests indicate that if the welds are properly made they will give as good service as continuous rail. Insofar as welds in steam roads in this country are concerned it is, of course, too early to give any information as to their serviceability in track.

The type of track used as standard on the D&H road is known as the M&L construction, is shown on attached print, and consists of heavy double shoulder tie plates locked to the ties with screw spikes independent of the rail. Spring clips and clip bolts fasten the rail to the plate. In all cases the track is well ballasted with stone to a depth of 14″ under the ties and the cribs are well filled. 7 × 9 × 8′-6″ red oak creosoted ties are used.

As to the method of doing the work at Albany—the rail had already been laid and the preparing of the railends for the installation was done in the field. The bevel and facing of the top being effected with a facing machine, and a larger cut at the bottom being made with an acetylene torch. In later installations the rail was faced and bevelled at the mill, leaving only the lower half of the section to be done in the field. At Mechanicville, the new rails were welded together while blocked up on the ties immediately alongside the old running rails, after which the track was taken out of service and the shift made. At Schenectady, on account of narrow and steep shoulders, of track where rail was to be installed and because of the fact that it was impossible to take the track out of service for the work it was impossible to do the welding on the ground. It was therefore decided to weld the rails on flat cars in a yard about 3 miles from the point of installation. Stretches of rail in lengths from 741 to 1481 ft., two lines to-

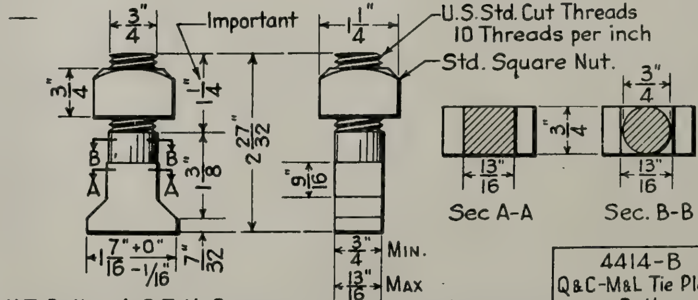


4447-B
Q&C-M&L Tie Plate
Type J for 130-131 RE Rail



Spring Steel Clip Tempered

4415
Q&C-M&L Spring Steel
Clip for M&L Tie Plate



H.T. Bolt – A.S.T.M. Spec.

4414-B
Q&C-M&L Tie Plate
Bolt

gether were loaded on flat cars and transported, without fastenings other than stakes placed on both sides of the rail on each car, around curves up to 10°. The 1482-ft. lengths were unloaded in about 16 minutes each.

The principal objection to long welded rails would of course seem to be the question of expansion. However, the D&H made an exhaustive investigation and a number of practical observations lead to the supposition that this factor is not so serious as it seemed. The D&H investigation developed the following facts:

> The Germans have found that the theoretical expansion in their long rails does not actually take place.
>
> Victorian railways in Australia, with rail lengths up to 250 ft., find with their standard track construction—spikes and ordinary joints—that their actual expansion and contraction is about one-half of the theoretical expansion.
>
> It would seem, therefore, that forces sufficient to resist a tendency for the rails to expand must come into action; such as, the lateral friction between ties, rail and ballast.
>
> Where rail is so fixed that it cannot expand into an extended position when heated and cannot move in any other way, as, for instance, by buckling, it must remain unaltered in length since the external stresses are greater than the inherent compressive stress set up by the temperature rise.
>
> Alternatively, if the rail cools below the temperature at which it is fixed, an inherent tensile stress will arise to be resisted by the influence which fixes the rail.
>
> While it is felt by European roads that the tendency of track to buckle under rises of temperature with long rails, is overcome in well ballasted and maintained track by the frictional resistance of the ties and ballast, this difficulty can be entirely eliminated by either allowing the track to take its set in its extended position in the extreme hot periods or by welding the track in hot weather, thereafter the only inherent stress will be tensile stress which will be greater in the cold months, but not sufficient to effect the service strength of the rails and at periods when it is desirable to work the track in spring, summer or fall, there will be only a small tensile stress and no stress in hot weather.
>
> European experience indicates that with long rails the tendency to expand or contract is greatly decreased; therefore, with the greater holding power of their construction, it was thought that rails could be welded in indefinitely long stretches without difficulty.
>
> Rail exposed to temperature changes of 100 degrees from that at which it was laid will be subject to a stress of about 19,000 lb. per square inch if the rail is fixed. This will amount to 247,000 lb. in a rail of 13 square-inch section, but it is well within the elastic limit of the steel, so that the rail will return to its original length when the initial temperature again prevails.
>
> The spring clip fastening sets up at each tie plate a spring pressure resistance to end movement of from 4,000 lb. to 5,000 lb. per tie, therefore, it would take approximately 200 ties or 360 ft. of track, on each side of the point of stress to prevent the movement of a rail of 13 square inches of section subjected to 100 degree temperature; however, in addition to resistance of the clip, they have binding resistance of the double shoulder tie plate and a frictional resistance between the tie plate and the rail, due to its own weight.
>
> The experience with long stretches of rail indicates that at the ends they have a little more, if any, expansion or contraction than would be expected with a 39-ft. rail in ordinary track construction.

This is the same conclusion reached by the German Engineers as given in the Thermit Corporation brochure "Thermit Rail Welding" and which is quoted below:

> "The German Engineers say the amount of movement at the ends regardless of the length is apparently only the normal movement for 40-ft. rails. The movements for 100, 200 and 400-ft. lengths were compared."

The actual experience of the D&H as to expansion effect of temperature on the installation at Albany checks very closely with the above. At the time the Albany installation was made, it was calculated that with a temperature range of 100 degrees which is not considered improbable in that section, the continuous 2700-ft. lengths of rail in the northbound track would, under unrestrained conditions, effect a change in length of approximately 1 ft. 9 in. Just what the change in length might be under the restraining influences of the track fastenings, particularly the double-shoulder tie plates and the spring rail clips, employed in the D&H construction, was a matter of conjecture but it was felt quite confidently that it would be only a relatively small proportion of the change that would occur under unrestrained conditions.

However, to be prepared for the worst possible condition, a special expansion joint was designed and installed 280-ft. from one end of one of the 1900-ft. lengths of rail in the southbound track, which is capable of absorbing the maximum change in length considered possible in this long rail, or, 1-ft. 10-in. Similar joints were planned for the other three long rails in the Albany installation, but before they were built, experience indicated definitely that they would not be required.

The long rails at Albany were welded together during the daytime when the temperature of the rail averaged about 125 degrees, and the final closure of the rails in the track was made when the rail temperature was above 130 degrees. Some days after the completion of the work when the rail temperature was considerably below 130 degrees one of the rails in the southbound track was cut to insert the special expansion joint. There was no perceptible movement of the long rail, and the joint was placed in position without difficulty. To the present time there has been practically no movement of the rail through the expansion joint in spite of the fact that the rail in the track, according to actual thermometer readings, has reached temperatures below zero and in excess of 130 degrees.

On December 29, 1933, when the temperature of the east rail was 5 degrees the joint opening at the north end was 5/16-in. and at the south end was ⅜-in. whereas on June 11, 1934 when the same rail had a temperature of 95 degrees, the openings at the same joints were 0 and 3/16-in. respectively. Similarly, considering the west rail, the north and south end joint openings on December 28, 1933, were 5/16 and ½-in. respectively, while the openings at the same joints on June 11, 1934 were 0 and ¼-in. Between the extremes of temperature recorded, the maximum change in size of any of the joint openings was 5/16-in., and that occurred at two joints which had a maximum opening of this amount when the rail registered a temperature of 5 degrees above zero.

The same condition was observed by the Committee on their inspection of the welded piece at Schenectady. There was no indication of any movement that could be detected between the clips and the rail throughout the entire stretch neither was there any indication of any movement in the joints on the end of this stretch above that which would be normal in a 39-ft. rail. It was noted at the time of the inspection that the insulated joint at the middle of the stretch was open approximately 1-in. but there semeed to be no indication of movement in the track on either side of this joint.

The D&H does not feel particularly concerned about the safety of its welded track in the event of a fractured weld, relying upon its double shoulder tie plate and spring rail clip construction to prevent the rail from getting out of alinement. If breaks occur at joints or elsewhere throughout the rails because of defects it is expected that joint bars will have to be applied temporarily and the breaks welded up later, adding a short section of rail in some cases to insure a sound rail structure. This was done on the breaks which occurred in the Albany stretch.

A study of the questionnaire would seem to indicate that so far in this country we have been able to weld track in long stretches in tunnels on steam roads with variations of temperature up to 75 degrees or over without provision for expansion except that made in ordinary track, that this track is of ordinary structure with cut spikes, the usual number of ties per rail, gravel or stone ballast and single or double shoulder tie plates. With the more rigid type of track such as the M&L in use on the D&H and the GEO in use on the Bessemer & Lake Erie it has been possible to weld rails in lengths up to 12,000 feet without any excessive movement either laterally or lengthwise with a temperature change up to 125 degrees.

As a general thing it has been possible to butt weld rails together without excessive failure and to good line and surface, this having been standard practice on the electric roads of this country for a good many years, a large amount of it being done on the European roads for the past five or six years and on railroads in this country as shown on the questionnaire.

The inspection by the Committee of the track on the D&H especially that piece at Schenectady convinced them that track of this type can be so welded as to allow perfect line and surface insofar as the joints are concerned.

The extra cost of rigid construction although in the case of the D&H running up to approximately $2000 per mile over the cost of ordinary track construction on heavily travelled roads with the same weight of rail will no doubt be reduced as time goes on in view of the fact that other similar types of track of cheaper construction are being developed at the present time.

As to the cost of the welds which seem high in the installation on the D&H there is no question but that as further work is carried on the price on the Thermit welds can be cut down considerably. In addition to this as given above there has already been developed in Germany a machine for the making of flash welds on rails and there is being developed at the present time in this country a machine which is designed to make flash welds in the field with the rail in track. In addition to this it is possible to purchase 66-ft. rails at a cost of $5.00 extra per ton and thus reduce the number of welds per mile from 270 to 160. It should be borne in mind, however, that controlled cooled rail cannot be purchased in this length at the present time.

The amount of saving which can be made in maintenance is problematical at the present time but some of the items on which this saving is anticipated are given below:

Elimination of rail-joints.
Increased life of rails through the elimination of end batter.
Saving in labor required in relaying rail through increased life of rail.
Reduced mechanical wear of joint ties with resultant increased life of these ties.
The substitution of a standard intermediate tie plate for the larger and more expensive plates used on the joints on some roads.
More efficient track signal circuits through the lower resistance of the welded joints, saving the cost of installation and maintenance of bonds.
Reduced maintenance of rolling stock and motive power.

In connection with the first item in various studies which the Committee on Economics of Railway Labor have made it has been figured that approximately 65 per cent of the track labor is chargeable to Account 220—Track Laying and Surfacing—and that in the vicinity of 75 per cent of this charge covers the labor used in tamping at or in the vicinity of the joint. Thus over 45 per cent of track labor is now necessary in order to keep the rail joint in proper line and surface. It goes without saying that if this amount of labor could be saved it would off-set the cost of the continuous welding of rails.

As against the saving shown above we have

The increased cost of the weld over the joint.
Possible increased cost of laying rail.
The increased cost of changing out rail in case of a break including the extra cost of the two welds required.

The Committee recommends that this be received as information.

Appendix C

(3) PLANS AND SPECIFICATIONS FOR TRACK TOOLS

W. L. Roller, Chairman, Sub-Committee; W. H. B. Bevan, E. W. Caruthers, H. R. Clarke, L. W. DesLauriers, F. S. Hales, E. T. Howson, J. B. Myers, C. J. Rist, J. R. Scatterday, I. H. Schram, G. M. Strachan.

In the Proceedings for 1935, Vol. 36, page 567, is shown Plan 12–A Carpenter's Adze. This plan was presented as information and to invite comment and criticism.

Committee has had under consideration a tentative plan of Scoop Shovels for use of trackmen and in collaboration with Mechanical and Purchases and Stores Divisions, wish to present Plan 26, dated March, 1936, for further study before adoption.

Committee also wishes to present for further study and criticism Appendix B, Conversion Graph dated 1936.

TABLE OF CONTENTS

PLAN NUMBER	*DESCRIPTION*	*GRADE STEEL*	*HARDNESS* (Brinell Numbers Shown Unless Otherwise Designated)
1	Clay Pick	O. H. or Alloy*	425–500
2	Tamping Pick	O. H. or Alloy*	425–500
3	Spike Mauls—No. 1 and No. 2	O. H. or Alloy*	425–500
4	Track Wrenches	O. H.	375–450
4–A	Track Wrenches	O. H.	375–450
5	Lining Bars	O. H.	300–375
6	Rail Tongs	O. H.	†
7	Tie Tongs	O. H.	†
8	Timber Tongs	O. H.	†
9	Spike Puller	O. H.	375–450
10	Rail Fork	O. H.	300–375
11	Claw Bar—No. 1	O. H.	300–375
11–A	Claw Bar—No. 2	O. H.	300–375
12	Track Adze	O. H. or Alloy*	375–450
12–A	Carpenter's Adze	O. H. or Alloy*	†
13	Double Faced Sledge	O. H. or Alloy*	425–500
14	Chisel End Tamping Bar	O. H.	425–500
15	Spear End Tamping Bar	O. H.	425–500
16	Track Chisel No. 1	O. H., Eec. or Alloy*	Point 477–532 Head 286–340
17	Track Chisel No. 2	Alloy*	†
18	Tie Plug Punch	Electric	Point 477–532 Head 286–340
19	Round Track Punch	Electric	Point 477–532 Head 286–340
20	Track Gage	Cast	†
21	Track Shovels	O. H. or Alloy*	45–50 (Rockwell)
22	Ballast Forks	O. H.	35–40 (Rockwell)
23			
24			
25	Track Tool Handles		
26	Scoops	O. H. or Alloy*	45–50 (Rockwell)

Appendix A Specifications for Track Tools
Appendix B General Information

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* No Hardness Specification for Alloy Steel.
† No Hardness tests required.

SPECIFICATIONS FOR TRACK TOOLS—1936

GENERAL SPECIFICATIONS

Workmanship and Finish

Each tool shall be finished in a workmanlike manner and shall be free from seams, cracks, irregularities of shape and other imperfections. Eyes of tools with handle holes must be on center and in true alinement.

Before leaving the factory, each tool shall be coated with paint, oil or varnish to prevent corrosion, and each polished cutting edge shall be oiled.

Marking

Each tool shall be plainly stamped with the manufacturer's name or brand and the purchaser's initials.

Inspection and Tests

Inspection of finished tools may, at the option of the purchaser, be made at the plant prior to shipment and the manufacturer shall afford the inspector, free of cost, all reasonable facilities to enable him to satisfy himself that the tools are in accordance with the plans and specifications. The tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works. Unless otherwise specified, the inspector shall select and test one finished tool from each lot of ten dozen or less, and the acceptance or rejection of each lot shall be determined by the results of this test.

In the detail specifications, the permissible variations are not to be construed to change the shape and general contour of the tool as indicated on the plans.

When Brinell hardness tests are specified, other recognized bases of measurement may be used, provided equal results are obtained. Before making Brinell test for hardness, surface where test is to be made shall be filed or ground off to a depth sufficient to give a true hardness indication.

Acceptance

In order to be accepted the tools must fulfill all the requirements of these specifications.

Shipment or Delivery

Tools shall be properly packed for shipment to avoid damage. All bundles and boxes shall be plainly marked with the name of the purchaser, the name of the manufacturer, and the point of shipment.

Manufacturer's Guarantee

The manufacturer shall guarantee that all tools are free from defects in material and workmanship and shall replace any tools found to be defective.

INSPECTION AND PHYSICAL TESTS

Clay Pick—Plan No. 1

No special tests required.

Tamping Pick—Plan No. 2

No special tests required.

Spike Mauls—Plan No. 3

Sample of each lot of ten dozen or less to be subjected to 1,000 full swinging blows for open-hearth steel and 3,000 full swinging blows for allow steel by continuous hand striking or the mechanical equivalent on a die block of Brinell, 400, without undue mushrooming or cracking of the face or edge of mushroom.

Track Wrenches—Plans Nos. 4—4A

One wrench to be tested from each lot of ten dozen or less by applying for one minute a load of 400 lb. at a point distant from the jaw end equal to 95 per cnet of the total length of the wrench without any spreading of the jaw or any permanent set in the handle.

Lining Bars—Plan No. 5

One bar to be tested from each lot of ten dozen or less by applying a load of 350 lb. 12-in. from the end of the handle, with the point suitably secured 3-in. from the end, without leaving a permanent set in excess of ¼-inch.

Rail Tongs—Plan No. 6

No special tests required.

Tie Tongs—Plan No. 7

No special tests required.

Timber Tongs—Plan No. 8

No special tests required.

Spike Puller—Plan No. 9

Sample of each lot manufactured to be tested in actual use by pulling a spike with a standard claw bar.

Rail Fork—Plan No. 10

No special tests required.

Claw Bar—Plans Nos. 11—11A

One bar from each lot of ten dozen or less to be tested by placing the claws of the bar ½-inch under the head of a standard track spike, rigidly placed and so located as to hold the bar in a horizontal position while a shock load equivalent to that of a 200 lb. weight falling a distance of one foot is applied to the handle at a point 5-in. from its end, without the toes showing any cracks or the handle taking any permanent set.

Track Adze—Plan No. 12

Test one adze in each lot of ten dozen or less by subjecting cutting edge to five normal blows on metal of the same composition as a railroad spike without breakage or serious nicking.

Carpenters Adze—Plan No. 12A

No special tests required.

Sledge—Plan No. 13

Sample of each lot of ten dozen or less to be subjected to 1,000 full swinging blows for open-hearth steel or 3,000 full swinging blows for alloy steel by continuous hand striking or the mechanical equivalent on a die block of Brinell 400, without undue mushrooming or cracking of the face or edge of mushroom.

Tamping Bar—Plans Nos. 14—15

No special tests required.

Track Chisel, Design No. 1—Plan No. 16
Track Chisel, Design No. 2—Plan No. 17

One chisel in each lot of ten dozen or less to be tested by cutting 100 linear inches in a rail head of Brinell 260 by mechanical or hand striking approximating service conditions, to a depth of 3/16-inch below original surface; in addition, striking three gouging blows of such intensity as to give for each blow a cut of approximately 1/16-inch in depth. The chisel point shall stand this test uninjured and the head shall stand up without undue battering.

Tie Plug Punch—Plan No. 18 and Round Track Punch—Plan No. 19

No special tests required.

Track Gage—Plan No. 20

No special tests required.

Track Shovel—Plan No. 21

See sheet Appendix A–8.

Ballast Fork—Plan No. 22

See sheet Appendix A–9.

Track Tool Handles—Plan No. 25

No special tests required.

Scoops—Plan No. 26

No special tests required.

HICKORY HANDLES FOR TRACK TOOLS

Handles 24-in. and longer shall conform to "Grades AA, AW or AR"; handles less than 24-in. to "Grades SAW or SAR" as set forth in Simplified Practice Recommendation No. 77 of the National Bureau of Standards, U.S. Department of Commerce, effective November 1st, 1927.

Design

Handles shall conform to the dimensions shown on plan No. 25 forming part of this specification, with an allowable variation of one-quarter inch over or under in length, and 1/16-inch over or under for all other dimensions. Eyes and dimensions of such handles are in accord with Simplified Practice Recommendation No. 17—Forged Tools, Bureau of Standards, U.S. Department of Commerce, effective April 1st, 1927.

Physical Requirements

Handles shall be of sound wood, thoroughly seasoned. The grain of the wood shall run parallel to the center of the handle, with an allowable variation of not over one inch in fifty inches.

Manufacture

(a) Handles shall be straight, uniform in size and shape for each type of tool, smoothly finished and waxed.

(b) Each handle shall be plainly marked for identification by the purchaser, with brand and identification mark, as specified by Simplified Practice Recommendation No. 77. Marking, unless otherwise specified by purchaser, shall be placed near the hand grasp end of handles and letters must not be less than ⅜-inch in height.

Inspection

(a) Handles will be inspected at points of manufacture, shipment or destination in suitable and convenient places satisfactory to the purchaser.

(b) Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while work on the contract of the purchaser is being performed, and shall have all reasonable facilities afforded them, free of cost, to satisfy them that the handles are being supplied in accordance with these specifications.

(c) Inspectors will make a reasonably close examination of each handle and the acceptance or rejection will be based on the inspector's knowledge of the appearance, weight and density required; rings of annual growth will not be counted nor handles weighed by scale unless the inspector's decisions are questioned. Exactness of size and shape will be checked by accurate measurements of handles taken at random.

Acceptance

In order to be accepted the handles must fulfill all the requirements of these specifications.

Delivery

Accepted handles shall be shipped by the seller in accordance with the instructions in the order covering them; they shall be securely packed in standard packages, each of which shall be marked to show seller's or manufacturer's name and the number, type and grade of the handles contained.

GRADE CLASSIFICATION AND WEIGHTS PER DOZEN FOR HANDLES, AND PLAN NUMBER REFERENCE

	Weight in Pounds per Dozen		*Plan Reference for Tools*
	Min.	*Max.*	
Grade "AA"			
Handles for Spike Mauls	14¼	17	Plan No. 3
Handles for Sledges	15	18	Plan No. 13
Grade "AW" or "AR"*			
Handles for Axes	17	20	
Handles for Adzes	15	18	Plan No. 12
Handles for Picks	21	26	Plan No. 1
Handles for Picks	21	26	Plan No. 2
Grade "SAW" or "SAR"**			
22″ Handles for Track Chisels	7½	11	Plans Nos. 16–17
22″ Handles for Tie Plug Punches	7½	11	Plan No. 18
22″ Handles for Track Punch	7½	11	Plan No. 19

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* NOTE.—If lower grade of handle is desired, grade "BW" or "BR" may be specified.
** NOTE.—If lower grade of handle is desired, grade "SAR" or "SAW" may be specified.

DEFINITION OF GRADES—HICKORY HANDLES

TAKEN FROM SIMPLIFIED PRACTICE RECOMMENDATIONS NO. 77—
U. S. DEPARTMENT OF COMMERCE

Handles 24-in. and Longer

Grade AA

Handles having not over 17 rings of annual growth per inch of radius; heavy weight, thrifty growth, all white, free from defects.

Grades AW and AR

Handles having not over 22 rings of annual growth per inch of radius, good weight, live growth, free from all defects. Handles of this grade will be supplied in all white wood, the grade symbol being AW; or in red, white, or mixed red and white, for which the symbol will be AR.

Grades BW and BR

Handles having not over 27 rings of annual growth per inch of radius, good weight, live growth. These grades permit such handles as have slight iron streaks not exceeding four in number running the entire length of the handle or the equivalent in shorter lengths. To be free from defects except in the first third of the length from the grasp end, or in the eye where is permitted one sound or tight knot or bird peck not over ¼-inch in diameter or two such knots or bird pecks where combined diameters do not exceed ¼-inch in diameter or slight deflection of grain. Handles of this grade will be supplied in white wood, the grade symbol being BW; or in red, white, or mixed red and white, for which the symbol will be BR.

Handles Less than 24-in. in Length

Grades SAW and SAR

Handles having not over 17 rings of annual growth per inch of radius, heavy weight, thrifty growth, free from all defects. Handles of this grade will be supplied in all white wood, the grade symbol being SAW; or in red, white, or mixed red and white, for which the symbol will be SAR.

Grades SBW and SBR

Handles of medium weight, live growth, permitting two slight iron streaks the entire length, or their equivalent in shorter streaks. Free from all defects. Handles of this grade will be supplied in all white wood, the grade symbol being SBW; or in red, white, or mixed red and white, for which the symbol will be SBR.

DEFINITION OF GRADES—ASH HANDLES

Taken from Simplified Practice Recommendation No. 76—
U. S. Department of Commerce

For Fork, Hoe, Rake and Shovel

Grade XX

Handles having not over 17 rings and not less than 5 rings of annual growth per inch of radius, heavy in weight, tough in texture, with straight grain. Slight cross at one end only will be allowed. Cross in grain not to exceed one inch in eight inches. Handles to be white, light red, mixed white and light red. Dark red-brown at tool end, extending not more than ten inches from end.

TRACK SHOVELS

(See General Specifications)

SCOPE AND DESIGN

This specification covers both the welded or riveted type and the solid shank type with either wood, malleable iron or combination wood-metal handle tops. Dimensions shall conform to plans, which are made a part of this specification. A variation of one-half inch more or less from the dimension shown on plan for length of strap or shank and handle will be allowed. A variation of ¼-in. more or less from the dimensions shown on plan for width or length of blade will be allowed, but the total variation in the over-all length of shovels shall not exceed ½-in. more or less of the dimensions shown on plan.

MATERIALS

Blades shall be of open hearth, crucible, electric furnace or alloy steel, with Rockwell hardness for carbon steel of 40 to 45.

Carbon steel blades shall be in thickness not less than No. 13 gage and alloy blades shall be of not less than No. 14 gage U. S. Standard. Gage to be measured at point where hardness is taken. For welded or riveted type, the straps shall be welded or riveted to the blade.

HANDLES AND TOPS

Handles shall be made of White Ash and shall conform to "Grade XX" as set forth in Simplified Practice Recommendation No. 76 of the Bureau of Standards, U.S. Department of Commerce. Handles shall be uniform in size and shape, thoroughly air seasoned and smoothly finished. Tops of handles shall be of the design specified and shall conform to plans that are made a part of this specification.

TESTS

One shovel from each lot of ten dozen or less shall be selected and metal straps (curved to fit contour of handle) shall be clamped to the upper and lower parts of the handle, after which the shovel shall be placed in a prying position, supported at the end of the blade by clamps and shall be capable of sustaining a load of 200 lb. suspended from the end for a period of two minutes without showing any permanent set, fracture or distortion.

Alloy steel shovels which have been given a heat treatment to insure uniformity in hardness shall be subjected to a shock test to insure against brittleness. The test shall be made by forcibly striking the blade of the shovel with a hand hammer at several places when placed on an anvil.

BALLAST FORKS

(See General Specifications)

SCOPE AND DESIGN

This specification covers either wood, malleable iron or combination wood-metal handle tops. Dimensions shall conform to plans, which are made a part of this specification. The total variation in the over-all length of forks shall not exceed ½-in. more or less of the dimensions shown on plan.

MATERIAL

Forks shall be made of high grade Open-Hearth Steel.
Tines of forks shall show Rockwell hardness of 35–40.
Straps shall be 0.04 U.S. Standard Gage Steel.

HANDLES

Handles shall be made of White Ash and shall conform to "Grade XX" as set forth in Simplified Practice Recommendation No. 76 of the National Bureau of Standards, U.S. Department of Commerce. Handles shall be straight, uniform in size and shape, thoroughly seasoned and smoothly finished.

Conclusions

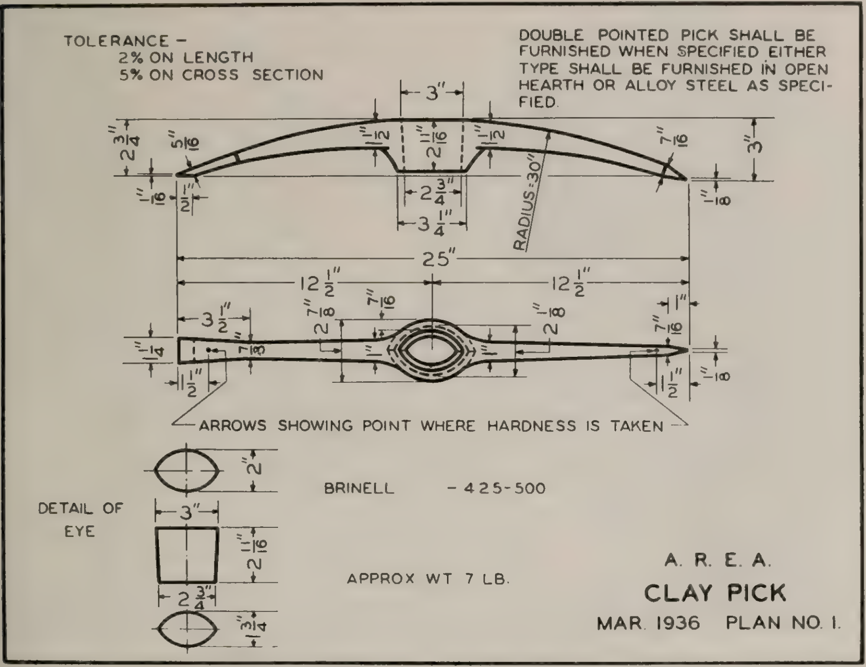
Committee recommends for adoption as recommended practice and printing in the Manual:

1. Plan 12-A dated 1936, A.R.E.A., Carpenter's Adze.

Plan 26, Scoop Shovel, is submitted as information only at this time with recommendation that the subject be handled further with view to arriving at a common standard with the Mechanical Division.

Appendix B—Conversion Graph for Hardness Tests is submitted as information.

Committee recommends this subject be continued with view to making further study of design of track tools, particularly those used in the laying of heavier rails.



TOLERANCE –
2% ON LENGTH
5% ON CROSS SECTION

DOUBLE POINTED PICK SHALL BE FURNISHED WHEN SPECIFIED EITHER TYPE SHALL BE FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED.

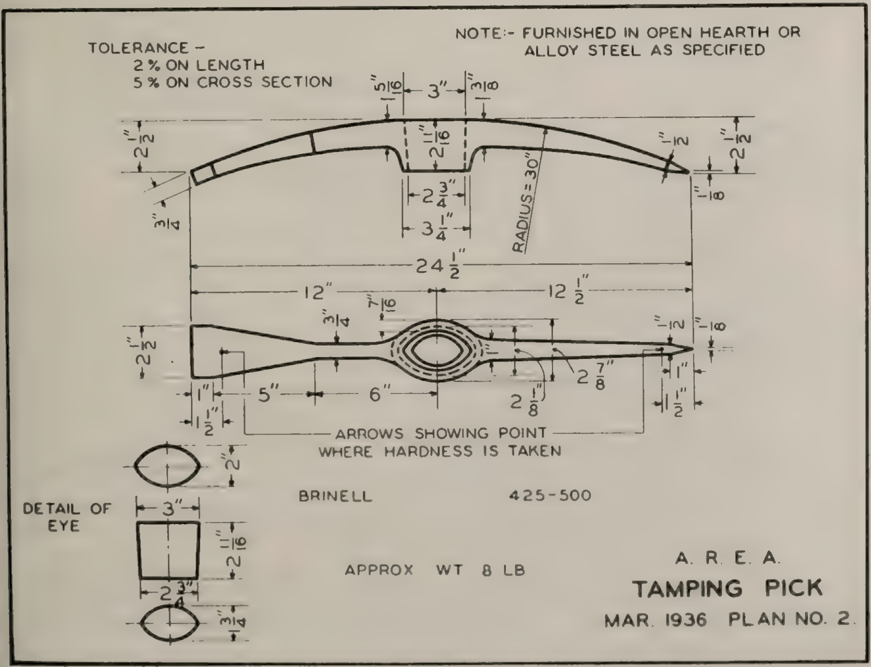
ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN

DETAIL OF EYE

BRINELL – 425-500

APPROX WT 7 LB.

A. R. E. A.
CLAY PICK
MAR. 1936 PLAN NO. 1.



NOTE:- FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED

TOLERANCE –
2 % ON LENGTH
5 % ON CROSS SECTION

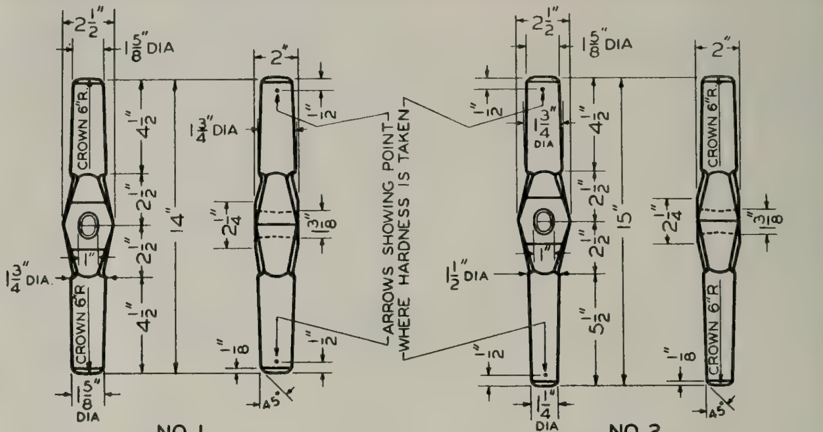
ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN

DETAIL OF EYE

BRINELL 425-500

APPROX WT 8 LB

A. R. E. A.
TAMPING PICK
MAR. 1936 PLAN NO. 2.



NO. 1
APPROX WEIGHT 10 LB

BRINELL 425-500

NO. 2
APPROX WEIGHT 10 LB

EYE TAPERED TO CENTER
4° ON LONG DIAMETER
3° ON SHORT DIAMETER.

TOLERANCE –
2% ON LENGTH
5% ON CROSS SECTION.

FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED.

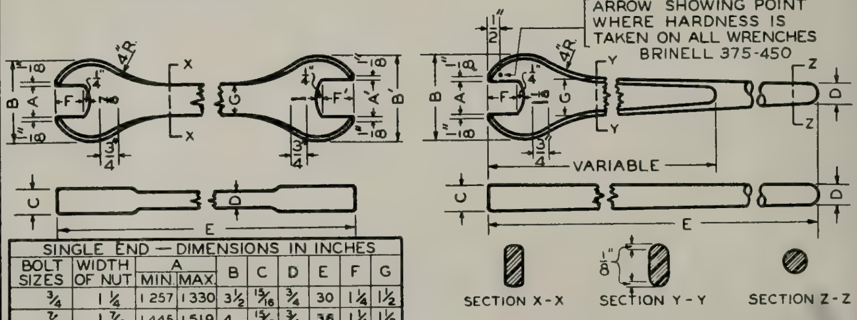
A. R. E. A.

SPIKE MAULS

MAR. 1936 PLAN NO. 3

TOLERANCE –
2% ON LENGTH
5% ON CROSS SECTION

ALL WRENCH JAWS SHALL BE MILLED TO DIMENSIONS SHOWN



ARROW SHOWING POINT WHERE HARDNESS IS TAKEN ON ALL WRENCHES
BRINELL 375-450

SINGLE END — DIMENSIONS IN INCHES									
BOLT SIZES	WIDTH OF NUT	A		B	C	D	E	F	G
		MIN.	MAX.						
3/4	1 1/4	1 257	1 330	3 1/2	15/16	3/4	30	1 1/4	1 1/2
7/8	1 7/16	1 445	1 519	4	15/16	3/4	36	1 1/4	1 1/2
1	1 3/8	1 634	1.709	4	15/16	7/8	42	1 3/8	1 1/2
1 1/8	1 13/16	1 822	1.898	4 1/8	15/16	7/8	48	1 9/16	1 1/2
1 1/4	2	2.011	2.088	4 1/2	1	7/8	48	1 3/4	1 1/2
1 3/8	2 3/16	2.199	2.277	5	1	7/8	54	1 15/16	1 1/2

DOUBLE END — DIMENSIONS IN INCHES														
BOLT SIZES	WIDTH OF NUT	A		A'		B	B'	C	D	E	F	F'	G
		MIN.	MAX.	MIN.	MAX.								
3/4 & 7/8	1 1/4 & 1 7/16	1 257	1 330	1.445	1 519	3 1/2	4	15/16	1/2	36	1 1/4	1 1/4	1 1/2
7/8 & 1	1 7/16 & 1 5/8	1 445	1.519	1.634	1.709	4	4	15/16	1/2	42	1 1/4	1 3/8	1 1/2
1 & 1 1/8	1 5/8 & 1 13/16	1 634	1.709	1 822	1 898	4	4 1/8	15/16	9/16	48	1 3/8	1 9/16	1 1/2
1 1/8 & 1 1/4	1 13/16 & 2	1 822	1 898	2.011	2.088	4 1/8	4 1/2	✱	9/16	48	1 9/16	1 3/4	1 1/2
1 1/4 & 1 3/8	2 & 2 3/16	2 011	2.088	2.199	2 277	4 1/2	5	1	9/16	48	1 3/4	1 15/16	1 1/2

✱ C = 15/16 ON 1 1/8 END, 1 ON 1 1/4 END.

SIZE OF BOLT SHALL BE STAMPED PLAINLY ON ONE SIDE OF HEAD IN POSITION AS SHOWN

SINGLE END WRENCH WILL BE FURNISHED WITH END TAPERED FOR LAST 6" TO 1/2" DIA AT END WHEN SPECIFIED

A.S.A.-HEAVY NUTS, ARE SAME AS, AND SUPERSEDES FORMER U.S. STD.

A. R. E. A.

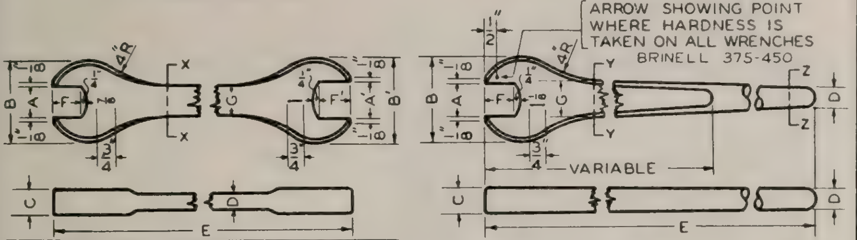
TRACK WRENCHES

FOR A.S.A.- HEAVY NUTS

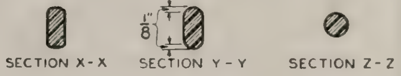
MAR. 1936 . PLAN NO. 4.

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

ALL WRENCH JAWS SHALL BE
MILLED TO DIMENSIONS SHOWN



SINGLE END — DIMENSIONS IN INCHES									
BOLT SIZES	WIDTH OF NUT	A		B	C	D	E	F	G
		MIN.	MAX						
3/4	1 1/8	1 132	1 205	3 3/8	15/16	3/4	30	1 1/8	1 1/2
7/8	1 5/16	1 320	1 394	3 7/8	15/16	3/4	36	1 1/8	1 1/2
1	1 1/2	1 508	1 583	3 7/8	15/16	7/8	42	1 1/4	1 1/2
1 1/8	1 11/16	1 696	1 771	4	15/16	7/8	48	1 7/16	1 1/2
1 1/4	1 7/8	1 885	1 961	4 3/8	1	7/8	48	1 5/8	1 1/2
1 3/8	2 1/16	2 073	2 150	4 7/8	1	7/8	54	1 13/16	1 1/2


SECTION X-X SECTION Y-Y SECTION Z-Z

SIZE OF BOLT SHALL BE STAMPED PLAINLY ON ONE SIDE OF HEAD IN POSITION AS SHOWN

SINGLE END WRENCH WILL BE FURNISHED WITH END TAPERED FOR LAST 6" TO 1/2" DIA AT END WHEN SPECIFIED

DOUBLE END — DIMENSIONS IN INCHES														
BOLT SIZES	WIDTH OF NUT	A		A'		B	B'	C	D	E	F	F'	G
		MIN	MAX	MIN	MAX								
3/4 & 7/8	1 1/8 & 1 5/16	1 132	1 205	1 320	1 394	3 3/8	3 7/8	15/16	1/2	36	1 1/8	1 1/8	1 1/2
7/8 & 1	1 5/16 & 1 1/2	1 320	1 394	1 508	1 583	3 7/8	3 7/8	15/16	1/2	42	1 1/8	1 1/4	1 1/2
1 & 1 1/8	1 1/2 & 1 11/16	1 508	1 583	1 696	1 771	3 7/8	4	15/16	9/16	48	1 1/4	1 7/16	1 1/2
1 1/8 & 1 1/4	1 11/16 & 1 7/8	1 696	1 771	1 885	1 961	4	4 3/8	*	9/16	48	1 7/16	1 5/8	1 1/2
1 1/4 & 1 3/8	1 7/8 & 2 1/16	1 885	1 961	2 073	2 150	4 3/8	4 7/8	1	9/16	48	1 5/8	1 13/16	1 1/2

* C = 15/16 ON 1 1/8 END, 1 ON 1 1/4 END

A R E A

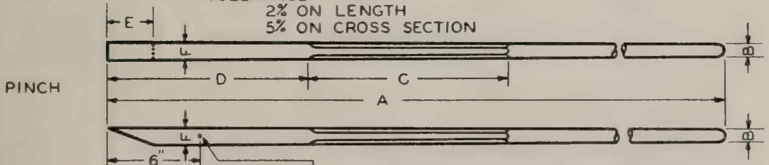
TRACK WRENCHES

FOR A.S.A.– REGULAR NUTS

MAR. 1936 PLAN NO. 4-A

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

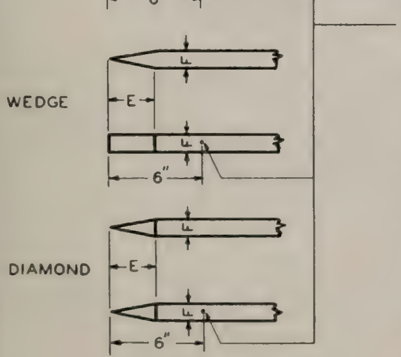
PINCH



ARROWS SHOWING POINT
WHERE HARDNESS IS TAKEN

WEDGE

DIAMOND



SCHEDULE OF DIMENSIONS						
APPROX. WEIGHT	A	B	C	D	E	F
18 LB	5'-0"	3/4"	14"	14"	3"	1 1/4"
20 "	5'-3"	3/4"	14"	14"	3"	1 1/4"
26 "	5'-6"	7/8"	14"	14"	3"	1 1/2"

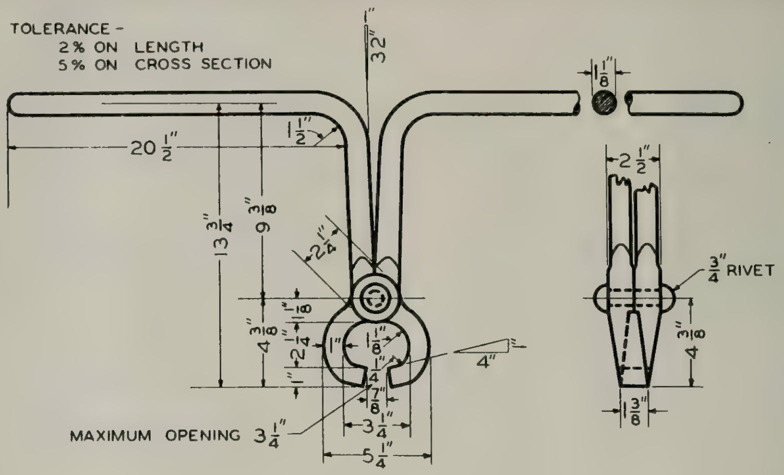
ORDER SHALL SPECIFY TYPE OF POINT AND LENGTH OF BAR

BRINELL 300 - 375

A. R. E. A.

LINING BAR

MAR. 1936 PLAN NO. 5



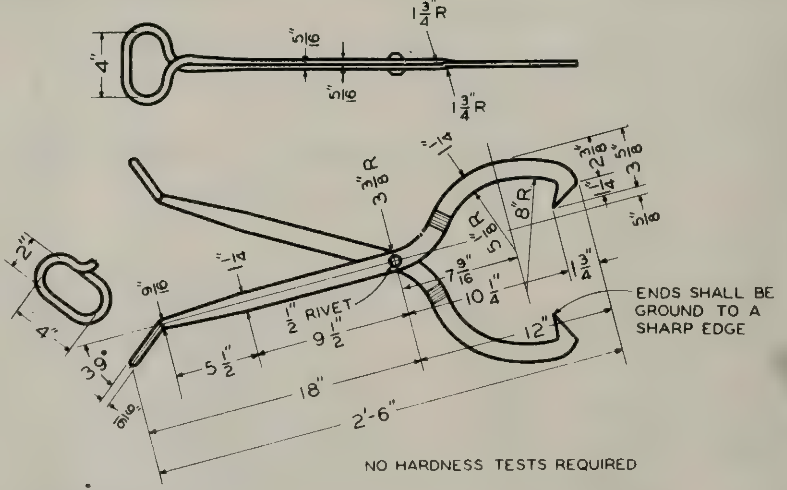
TOLERANCE -
2 % ON LENGTH
5 % ON CROSS SECTION

MAXIMUM OPENING 3 1/4"

NO HARDNESS TESTS REQUIRED

APPROX WT 22 LB

A. R. E. A.
RAIL TONGS
MAR. 1936 PLAN NO. 6.



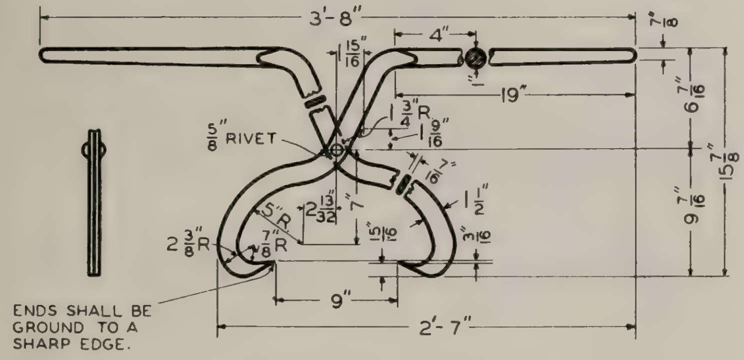
ENDS SHALL BE GROUND TO A SHARP EDGE

NO HARDNESS TESTS REQUIRED

TOLERANCE—
2 % ON LENGTH
5 % ON CROSS SECTION

APPROX WT 8 LB

A R E A
TIE TONGS.
MAR. 1936 PLAN NO. 7.



ENDS SHALL BE GROUND TO A SHARP EDGE.

NO HARDNESS TESTS REQUIRED

TOLERANCE —
2 % ON LENGTH
5 % ON CROSS SECTION

APPROX WT 17 LB

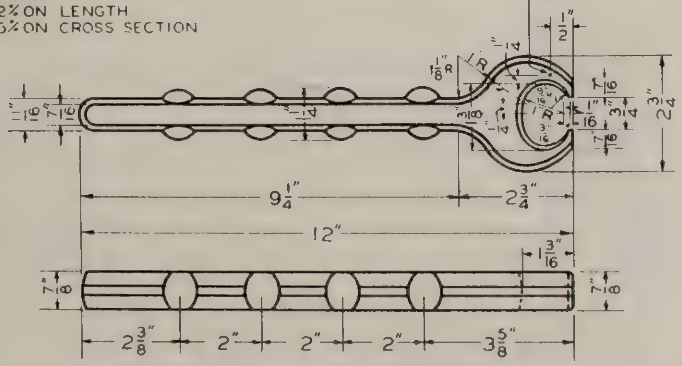
A. R. E. A.

TIMBER TONGS

MAR. 1936 PLAN NO. 8.

ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION



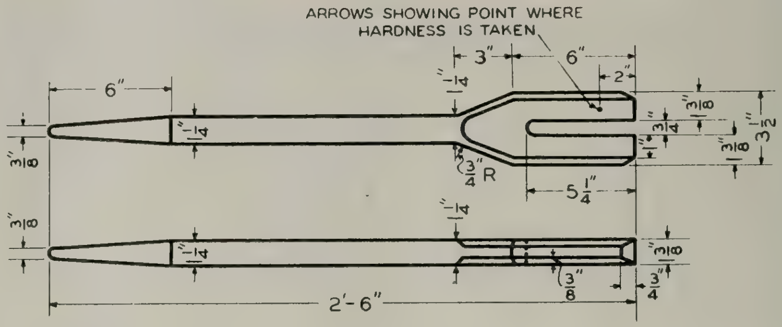
BRINELL — 375 - 450

APPROX WT 2 1/2 LB

A R E. A

SPIKE PULLER

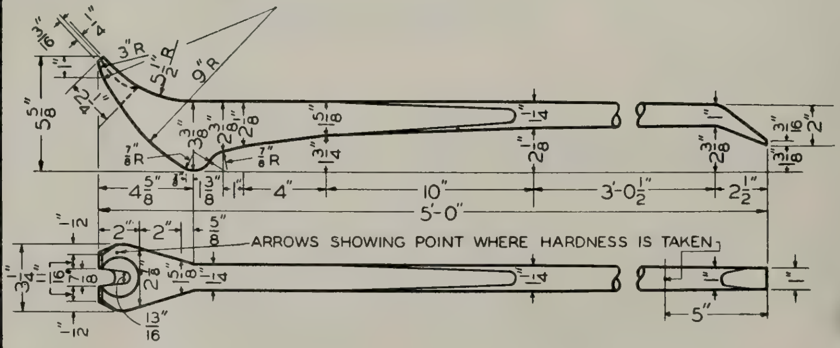
MAR. 1936 PLAN NO 9



TOLERANCE —
2 % ON LENGTH
5 % ON CROSS SECTION

BRINELL 300-375
APPROX WT 13 LB

A. R. E. A.
RAIL FORK
MAR. 1936 PLAN NO. 10.

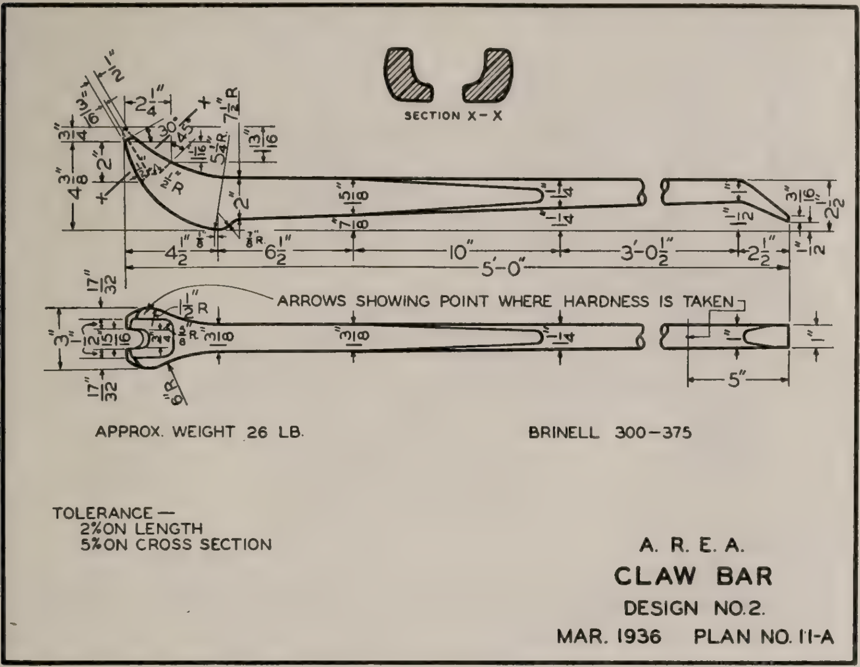


APPROX WEIGHT 26 LB.

BRINELL 300—375

TOLERANCE —
2%ON LENGTH
5%ON CROSS SECTION

A. R. E. A.
CLAW BAR
DESIGN NO.1.
MAR. 1936 PLAN NO. 11.

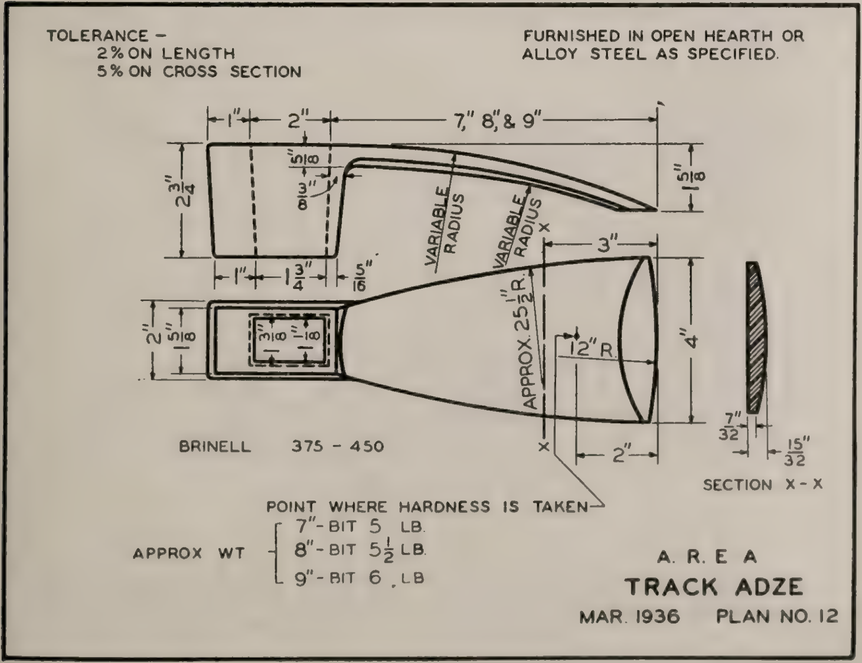


APPROX. WEIGHT 26 LB.

BRINELL 300–375

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

A. R. E. A.
CLAW BAR
DESIGN NO. 2.
MAR. 1936 PLAN NO. 11-A



TOLERANCE –
2% ON LENGTH
5% ON CROSS SECTION

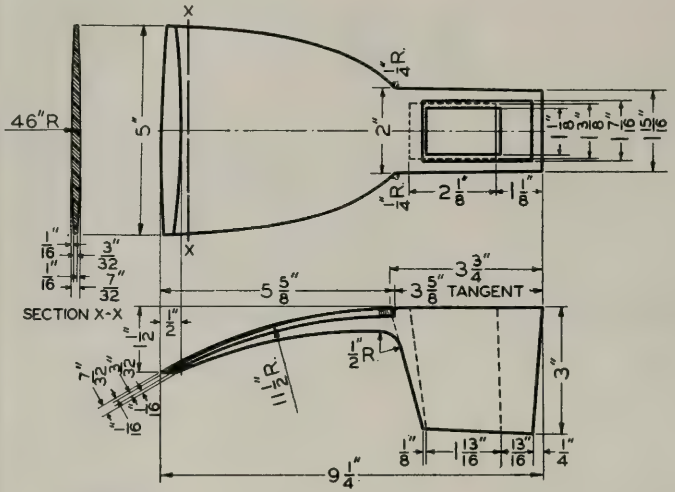
FURNISHED IN OPEN HEARTH OR
ALLOY STEEL AS SPECIFIED.

BRINELL 375 - 450

POINT WHERE HARDNESS IS TAKEN

APPROX WT
- 7"-BIT 5 LB.
- 8"-BIT 5 1/2 LB.
- 9"-BIT 6 LB

A. R. E A
TRACK ADZE
MAR. 1936 PLAN NO. 12



TOLERANCE –
2% ON LENGTH
5% ON CROSS SECTION

FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED

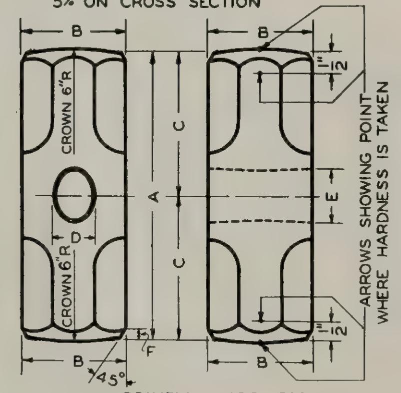
A. R. E. A.

CARPENTERS ADZE

MAR. 1935 PLAN NO. 12-A

TOLERANCE –
2% ON LENGTH
5% ON CROSS SECTION

FURNISHED IN OPEN HEARTH OR ALLOY STEEL AS SPECIFIED



BRINELL 425 – 500

SCHEDULE OF DIMENSIONS IN INCHES						
APPROX. WEIGHT	A	B	C	D	E	F
6 LB.	6	$2\frac{1}{8}$	3	1	$1\frac{3}{8}$	$\frac{3}{16}$
8 LB.	$6\frac{1}{2}$	$2\frac{1}{4}$	$3\frac{1}{4}$	1	$1\frac{3}{8}$	$\frac{3}{16}$
10 LB	7	$2\frac{1}{2}$	$3\frac{1}{2}$	1	$1\frac{3}{8}$	$\frac{1}{4}$
12 LB	$7\frac{1}{2}$	$2\frac{5}{8}$	$3\frac{3}{4}$	1	$1\frac{3}{8}$	$\frac{1}{4}$
14 LB.	8	$2\frac{3}{4}$	4	1	$1\frac{3}{8}$	$\frac{1}{4}$
16 LB.	$8\frac{1}{4}$	$2\frac{7}{8}$	$4\frac{1}{8}$	1	$1\frac{3}{8}$	$\frac{1}{4}$

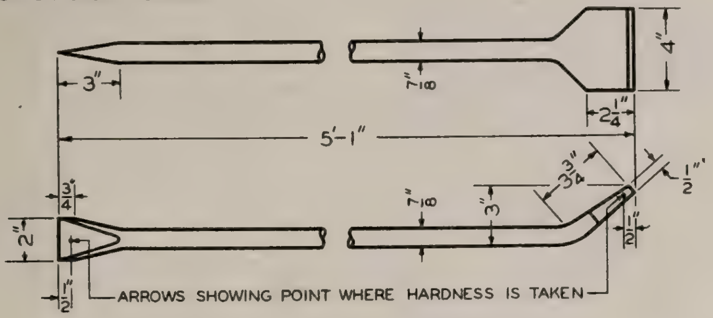
EYE TAPERED TO CENTER
4° ON LONG DIAMETER
3° ON SHORT DIAMETER

A R E A

DOUBLE FACED SLEDGE

MAR. 1936 PLAN NO. 13

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

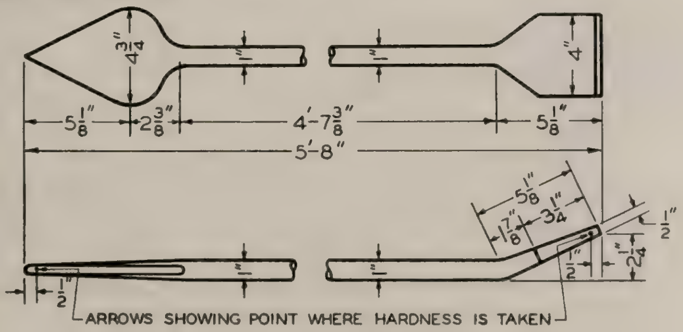


BRINELL 425 – 500

APPROX WT 13 LB

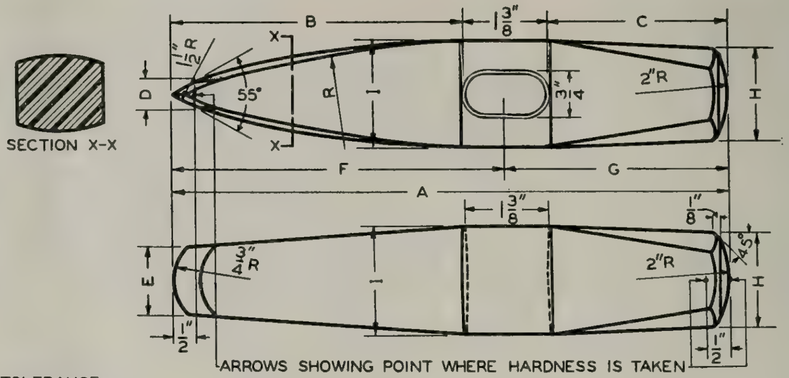
A. R. E A
CHISEL END TAMPING BAR
MAR. 1936 PLAN NO. 14

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION



BRINELL 425 – 500
APPROX. WT 15 LB.

A. R. E. A.
SPEAR END TAMPING BAR
MAR. 1936 PLAN NO. 15

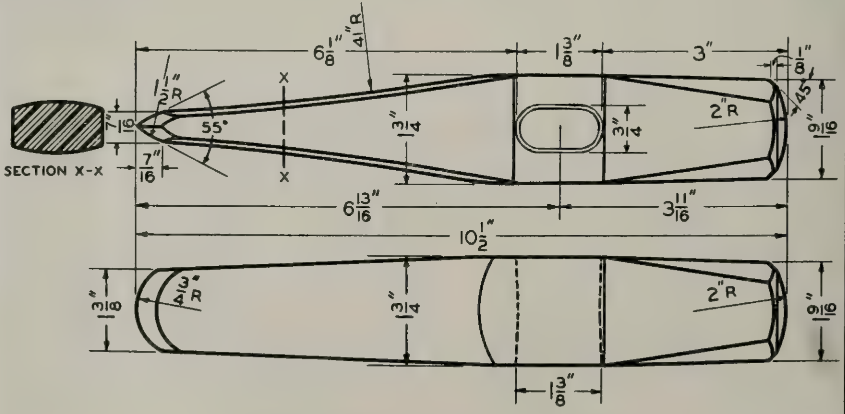


TOLERANCE—
2% ON LENGTH, 5% ON CROSS SECTION.
EYE TAPERED TO CENTER
4° ON LONG DIAMETER
3° ON SHORT DIAMETER.
FURNISHED IN OPEN HEARTH, ELECTRIC, OR
ALLOY STEEL AS SPECIFIED.

BRINELL POINT 477-532
BRINELL HEAD 286-340

APPROX. WT.	A	B	C	D	E	F	G	H	I	R
$5\frac{1}{4}$ LBS.	$9\frac{1}{4}''$	$4\frac{7}{8}''$	3"	$\frac{7}{16}''$	$1\frac{1}{8}''$	$5\frac{9}{16}''$	$3\frac{11}{16}''$	$1\frac{9}{16}''$	$1\frac{3}{4}''$	$18\frac{7}{8}''$
$6\frac{1}{4}$ LBS.	$10\frac{1}{2}''$	$6\frac{1}{8}''$	3"	$\frac{7}{16}''$	$1\frac{1}{8}''$	$6\frac{13}{16}''$	$3\frac{11}{16}''$	$1\frac{9}{16}''$	$1\frac{3}{4}''$	$33\frac{1}{4}''$

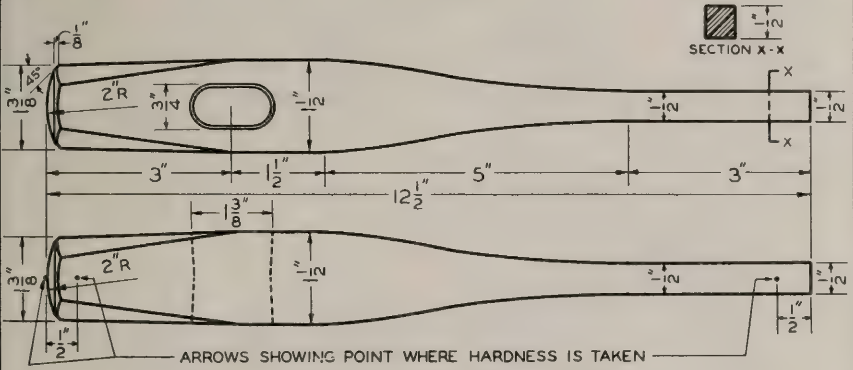
A. R. E. A.
TRACK CHISEL
DESIGN NO. 1.
MAR. 1936 PLAN NO. 16.



THIS DESIGN FURNISHED IN ALLOY STEEL ONLY
APPROX. WEIGHT $5\frac{1}{2}$ LB.

TOLERANCE—
2% ON LENGTH, 5% ON CROSS SECTION.
EYE TAPERED TO CENTER
4° ON LONG DIAMETER
3° ON SHORT DIAMETER

A. R. E. A.
TRACK CHISEL
DESIGN NO. 2.
MAR. 1936 PLAN NO. 17.



ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN

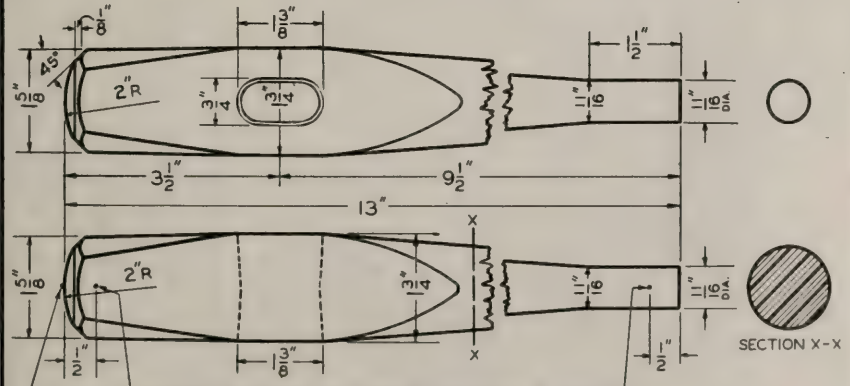
BRINELL—POINT — 477-532
HEAD — 286-340

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

APPROX. WEIGHT 4 LB.

EYE TAPERED TO CENTER
4° ON LONG DIAMETER
3° ON SHORT DIAMETER

A. R. E. A.
TIE PLUG PUNCH
MAR 1936 PLAN NO. 18



ARROWS SHOWING POINT WHERE HARDNESS IS TAKEN

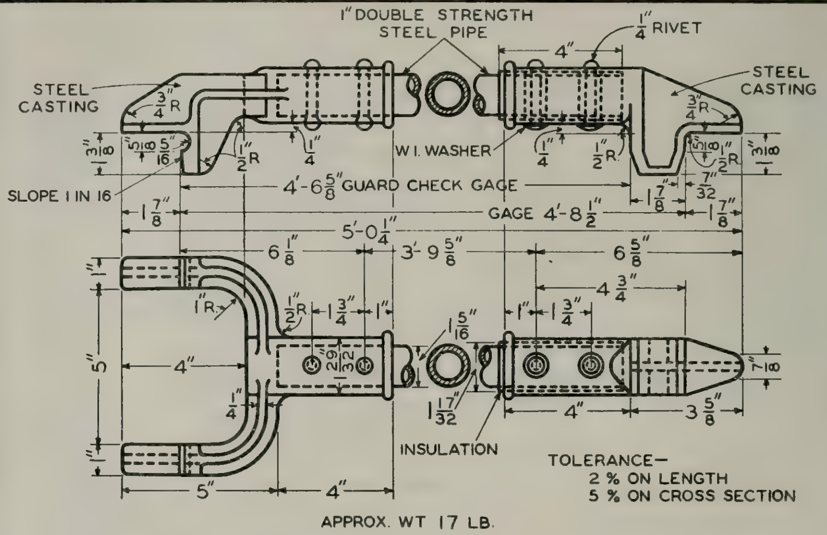
APPROX. WEIGHT 5½ LB.

BRINELL—POINT 477–532
HEAD 286–340

TOLERANCE —
2% ON LENGTH
5% ON CROSS SECTION

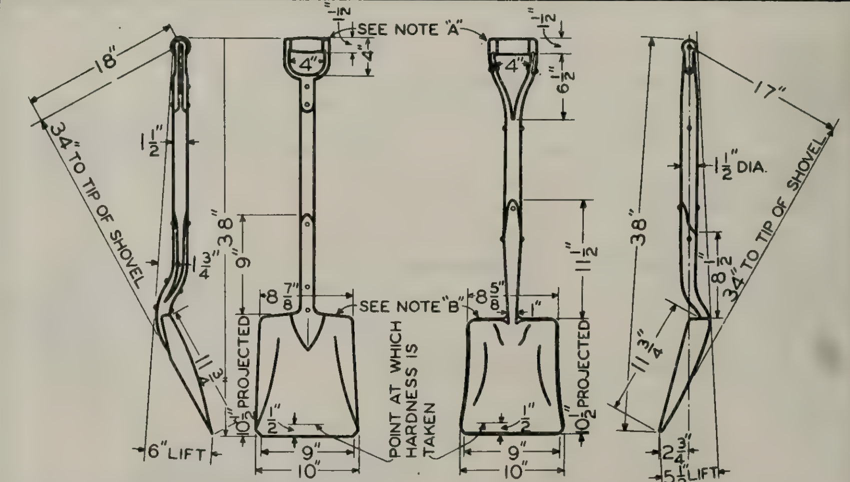
EYE TAPERED TO CENTER
4° ON LONG DIAMETER
3° ON SHORT DIAMETER

A. R. E. A.
ROUND TRACK PUNCH
MAR. 1936 PLAN NO. 19.



NOTE:
INSULATE BY USE OF FIBRE BUSHINGS AT BOTH ENDS WHEN REQUIRED.
CENTER LINE TO BE MARKED ON GAGE WHEN REQUIRED.
NO TOLERANCE ALLOWED IN GAGE DISTANCE.

A. R. E. A.
TRACK GAGE
MAR. 1936 PLAN NO. 20.



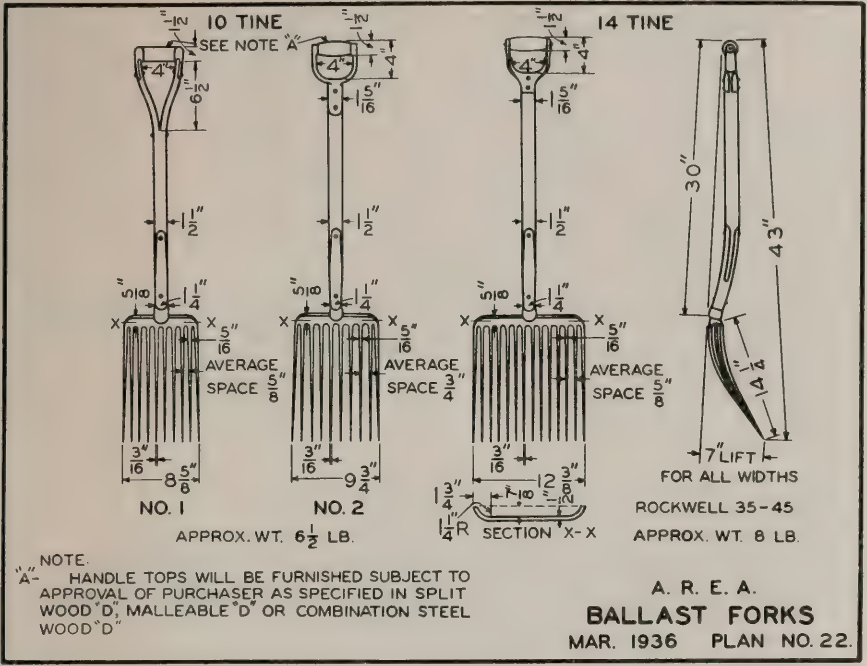
WELDED OR RIVETED TYPE

SOLID SHANK TYPE

NOTE:
"A"— HANDLE TOPS WILL BE FURNISHED SUBJECT TO APPROVAL OF PURCHASER AS SPECIFIED IN SPLIT WOOD "D", MALLEABLE "D" OR COMBINATION STEEL WOOD "D"
"B"— FOOT TREAD ON TOP OF BLADE APPROX. 1/2" WIDE SHALL BE FURNISHED WHEN SPECIFIED.

ROCKWELL 45-50

A. R. E. A.
TRACK SHOVELS
MAR. 1936 PLAN NO. 21.

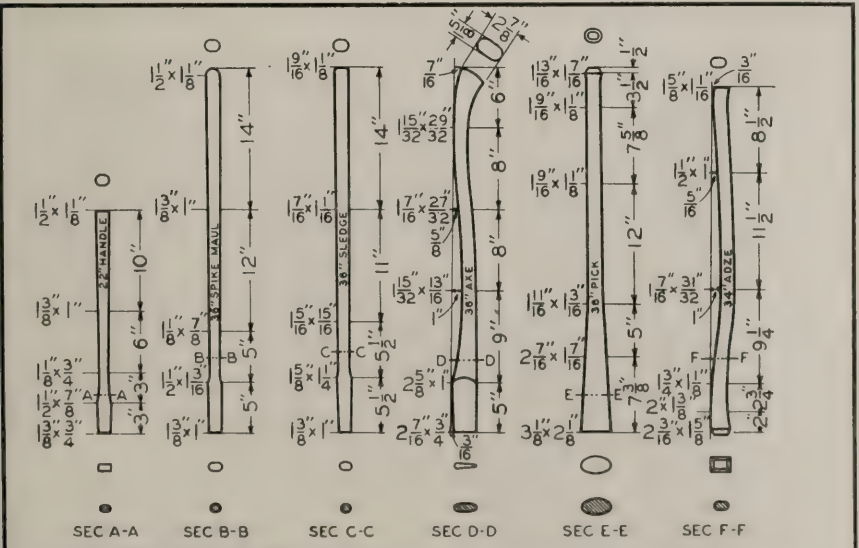


NOTE.
"A"- HANDLE TOPS WILL BE FURNISHED SUBJECT TO APPROVAL OF PURCHASER AS SPECIFIED IN SPLIT WOOD "D", MALLEABLE "D" OR COMBINATION STEEL WOOD "D"

A. R. E. A.

BALLAST FORKS

MAR. 1936 PLAN NO. 22.

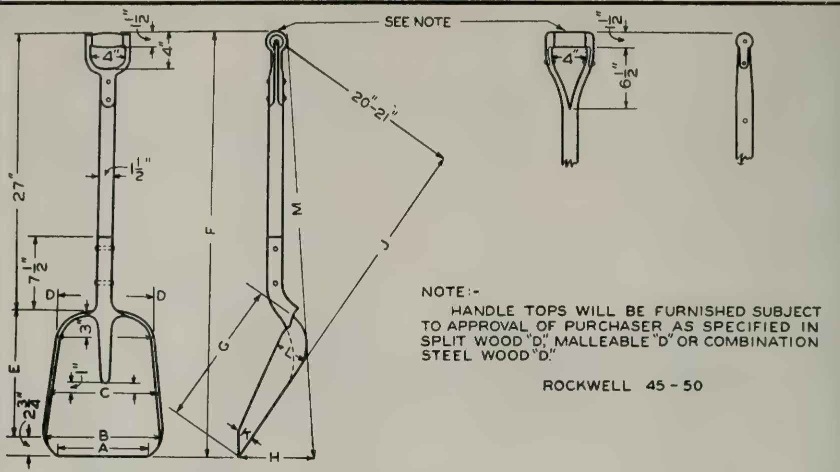


EYE DIMENSIONS OF ABOVE HANDLES ARE IN ACCORD WITH SIMPLIFIED PRACTICE RECOMMENDATION NO. 17-FORGED TOOLS-BUREAU OF STANDARDS. U. S DEPARTMENT OF COMMERCE.

A. R. E. A.

TRACK TOOL HANDLES

MAR. 1936 PLAN NO. 25.



NOTE:-

HANDLE TOPS WILL BE FURNISHED SUBJECT TO APPROVAL OF PURCHASER AS SPECIFIED IN SPLIT WOOD "D," MALLEABLE "D" OR COMBINATION STEEL WOOD "D."

ROCKWELL 45 - 50

TABLE OF DIMENSIONS - SIZES NO 2 TO 7

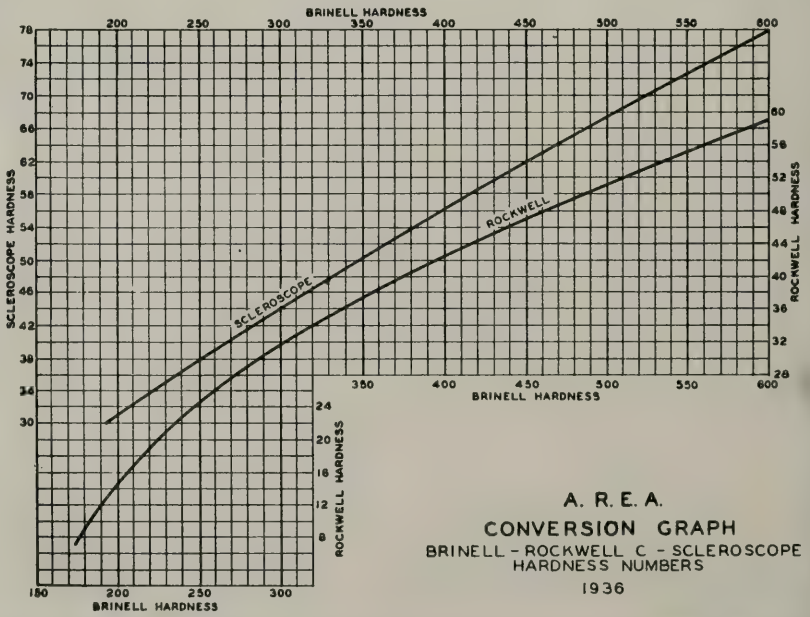
SIZE	A	B	C	D	E	F	G	H	J	K	L	M
2	10½″	11¾″	11″	9″	15″	40¾″	12½″	7″	35″	1⅜″	3⅜″	40¾″
3	10¾″	11⅞″	11⅛″	9⅛″	15½″	41¼″	13″	7¼″	35½″	1½″	3½″	41¼″
4	11″	12″	11¼″	9¼″	16″	41¾″	13½″	7⅜″	36″	1⅝″	3⅝″	41¾″
5	11¼″	12⅛″	11⅜″	9⅜″	16½″	42¼″	14″	7½″	36½″	1¾″	3¾″	42¼″
6	11½″	12¼″	11½″	9½″	17″	42¾″	14½″	7⅝″	37″	1⅞″	3⅞″	42¾″
7	11¾″	12⅜″	11⅝″	9⅝″	17½″	43¼″	15″	7¾″	37½″	2″	4″	43¼″

TOLERANCE + OR - ¼″

A. R. E. A.

SCOOP

MAR. 1936 PLAN NO. 26



A. R. E. A.

CONVERSION GRAPH

BRINELL - ROCKWELL C - SCLEROSCOPE HARDNESS NUMBERS

1936

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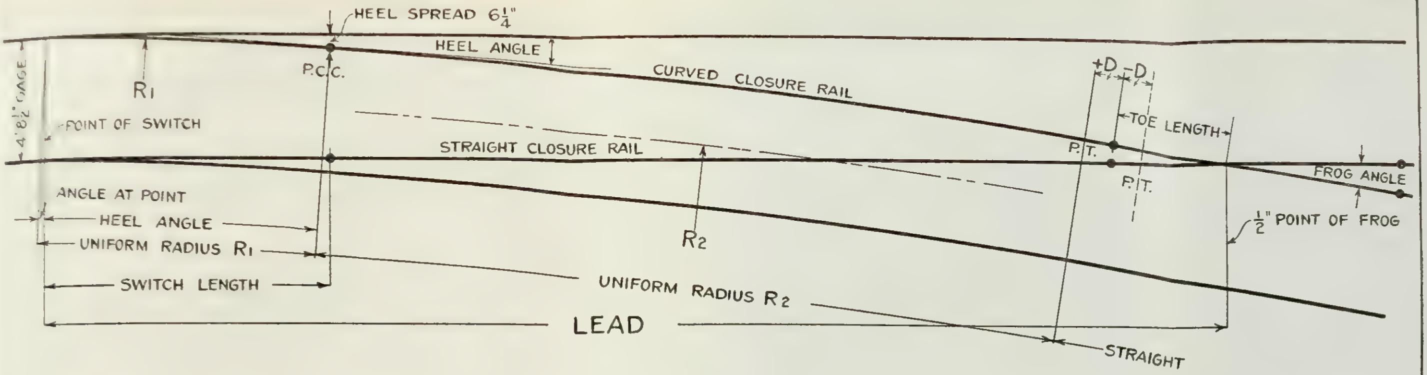


FROG	CURVED SWITCHES (HEEL SPREAD 6¼")								FROG	LEAD	CURVE DATA			CLOSURE RAILS				FROG DATA		FROG
Nº	LENGTH	HEEL ANGLE	RECOMMENDED,		INFORMATION				Nº		CENTER LINE RAD. R2	DEGREE OF CURVE	DISTANCE D	STRAIGHT		CURVED		ANGLE	TOE LENGTH	Nº
			POINT 0" THICK ✳		POINT ⅛" THICK ✳		POINT ¼" THICK ✳							TOTAL LENGTH	SUGGESTED RAILS	TOTAL LENGTH	SUGGESTED RAILS			
			ANGLE AT PT.	RAD. R1.	ANGLE AT PT.	RAD. R1.	ANGLE AT PT.	RAD. R1												
5	11'-0"	3°55'27"	1°-30'	260.01'	1°23'43"	249.21'	1°17'13"	238.98'	5	40'-6¼"	196.40'	29°29'53"	0.00'	25'-8¼"	25'-8¼"	26'-0"	26'-0"	11°25'16"	3'-10"	5
6									6	45'-6½"	321.23'	17°54'33"	-1.37'	30'-0"	30'-0"	30'-3¼"	30'-3¼"	9°31'38"	4'-6½"	6
7	19'-6"	2°13'37"	0°-50'	801.69'	0°46'22"	768.32'	0°42'42"	737.31'	7	62'-8"	360.11'	15°57'42"	-0.38'	37'-0"	37'-0"	37'-2¾"	37'-2¾"	8°10'16"	6'-2"	7
8									8	67'-9¾"	490.19'	11°42'32"	0.00'	42'-1¾"	30'-0" 12'-1¾"	42'-4"	30'-0" 12'-4"	7°09'10"	6'-2"	8
9									9	72'-10½"	654.46'	8°45'47"	0.00'	47'-2½"	30'-0" 17'-2½"	47'-4½"	30'-0" 17'-4½"	6°21'35"	6'-2"	9
10									10	77'-5"	839.90'	6°49'33"	-0.34'	50'-11"	33'-0" 17'-11"	51'-1"	33'-0" 18'-1"	5°43'29"	7'-0"	10
11									11	81'-11¼"	1073.18'	5°20'27"	-0.32'	55'-5¼"	39'-0" 16'-5¼"	55'-6¾"	39'-0" 16'-6¾"	5°12'18"	7'-0"	11
12	30'-0"	1°24'22"	0°-35'	2089.34'	0°32'37"	1993.19'	0°30'14"	1905.36'	12	103'-9½"	1113.06'	5°08'58"	+0.61'	66'-0"	33'-0" 33'-0"	66'-1½"	33'-0" 33'-1½"	4°46'19"	7'-9½"	12
14									14	113'-6¾"	1585.35'	3°36'53"	+0.66'	74'-11¼"	30' 30' 14'-11¼"	75'-0¾"	30' 30' 15'-0¾"	4°05'27"	8'-7½"	14
15									15	118'-4½"	1876.94'	3°03'11"	-0.06'	78'-11½"	33' 30' 15'-11½"	79'-0½"	33' 30' 16'-0½"	3°49'06"	9'-5"	15
16									16	123'-4½"	2234.00'	2°33'54"	-0.78'	83'-11½"	33' 33' 17'-11½"	84'-0½"	33' 33' 18'-0½"	3°34'47"	9'-5"	16
18	39'-0"	1°06'49"	0°-25'	3206.14'	0°23'10"	3071.56'	0°21'20"	2947.64'	18	146'-0"	2632.48'	2°10'36"	+0.92'	95'-11½"	39' 39' 17'-11½"	96'-0½"	39' 39' 18'-0½"	3°10'56"	11'-0½"	18
20									20	156'-0½"	3478.36'	1°38'50"	-0.27'	106'-0"	39' 39' 28'	106'-1"	39' 39' 28'-1"	2°51'51"	11'-0½"	20

✳ NOTES ON THICKNESS OF POINT

RECOMMENDED
- 0" THICK:– POINT HOUSED INTO STOCK RAIL; THEORETICAL GAGE LINES OF SWITCH AND STOCK RAILS INTERSECT AT POINT OF SWITCH. ACTUAL THICKNESS OF POINT ⅛" AND STOCK RAIL MACHINED ACCORDINGLY.

INFORMATION
- ⅛" THICK:– THEORETICAL GAGE LINES OF SWITCH AND STOCK RAILS ⅛" APART AT POINT OF SWITCH. POINT CHAMFERED TO $\frac{1}{16}$" THICK IF DESIRED STOCK RAIL NOT MACHINED.
- ¼" THICK:– THEORETICAL GAGE LINES OF SWITCH AND STOCK RAILS ¼" APART AT POINT OF SWITCH POINT CHAMFERED TO $\frac{1}{16}$" OR ⅛" THICK PER PLANS 101 TO 108. STOCK RAIL NOT MACHINED.

A. R. E. A.
TURNOUT DATA FOR CURVED SWITCHES

PLAN NO. 920

March, 1936

Appendix D

(4) PLANS FOR SWITCHES, FROGS, CROSSINGS, SLIP SWITCHES, ETC., AND TRACK CONSTRUCTION IN PAVED STREETS

E. W. Caruthers, Chairman, Sub-Committee; C. A. Alden, W. H. Bettis, L. H. Bond, O. U. Cook, L. W. DesLauriers, J. A. Ellis, F. W. Gardiner, C. R. Harding, O. F. Harting, N. M. Hench, F. W. Hillman, W. G. Hulbert, T. T. Irving, A. A. Johnson, F. H. Masters, W. A. Murray, J. B. Myers, G. A. Peabody, J. A. Reed, O. C. Rehfuss, C. J. Rist, E. M. T. Ryder, H. C. Stiff, J. R. Scatterday, W. Shea, G. J. Slibeck, J. B. Strong, E. D. Swift, H. N. West, J. G. Wishart, M. J. T. Zeeman.

Curved Switches

The necessity for high operating speeds makes the use of curved switches desirable in turnouts and crossovers. By their use the angle of impingement may be reduced materially, the radius of curvature throughout the turnout increased and in most cases the length of lead from point of switch to point of frog is decreased.

The use of curved switches will, therefore, provide greater safety and comfort, improved operating conditions for long rigid wheel-base locomotives, and economies in congested terminals where a shorter length of lead makes savings possible that could not be obtained with longer leads.

Plan 920 shows lengths, angles, and radii of curved switches; lengths and radii of leads and closure rails for turnouts of various frog angles from No. 5 to No. 20, both inclusive. This plan was prepared in conference with the Standardization Committee of the Manganese Track Society.

Conclusions

The Committee recommends that Plan 920 be adopted as recommended practice and published in the Manual.

The Committee has under consideration revisions to a number of plans now appearing in the book of trackwork plans, but is not prepared to present a report at this time, recommending that the work be continued.

Appendix E

(5) CORROSION OF RAIL AND FASTENINGS IN TUNNELS

R. W. E. Bowler, Chairman, Sub-Committee; O. U. Cook, L. W. DesLauriers, T. T. Irving, C. M. McVay, S. H. Poore, G. L. G. Smith, Dr. Hermann von Schrenk.

The Committee reports progress, but is not sufficiently prepared to present a report this year. It is recommended that the subject be continued.

Appendix F

(7) DESIGN OF TIE PLATES FOR RE RAIL SECTIONS AS DEVELOPED

J. de N. Macomb, Chairman, Sub-Committee; C. A. Alden, W. H. Bettis, W. H. B. Bevan, Blair Blowers, C. W. Breed, H. R. Clarke, O. U. Cook, L. W. DesLauriers, J. A. Ellis, F. W. Gardiner, C. R. Harding, N. M. Hench, F. W. Hillman, A. A. Johnson, G. M. Magee, W. A. Murray, J. B. Myers, S. H. Poore, J. A. Reed, Jr., E. M. T. Ryder, J. R. Scatterday, William Shea, G. L. G. Smith, G. M. Strachan, C. R. Strattman, Dr. Hermann von Schrenk, J. R. Watt, J. G. Wishart.

During the current year, the Committee has continued its studies of this subject, and presents, herewith, Plans Nos. 1 to 6, inclusive.

These designs have the following characteristics:

Width, of all designs, 7¾ inches.

This width was selected as utilizing the available face of a nominal 8-inch tie.

Plan No.	*Length*	*Ends*	*For use with*	*Eccentricit*
1	10½ inches	Inclined	112 lb. R.E. Rail	⅜ inch
2	11 "	"	112 " " "	⅜ "
3	12 "	"	131 " " "	⅜ "
4	12 "	Flat	112 " " "	¼ "
5	13 "	"	131 " " "	¼ "
6	14 "	"	131 " " "	½ "

Plans Nos. 2, 3, 4 and 5 consist of two pairs of designs, two designs for use with 112-lb. R.E. rail and two for use with 131-lb. R.E. rail; in each case, one design with flat ends for use with screw "Hold Down" spikes and one design with inclined ends for use with cut "Hold Down" spikes, or not to be separately attached to the tie.

Plan No. 1 is a 10½-inch section to be used instead of Plan No. 2, when traffic conditions do not justify the use of the larger tie plate.

Plan No. 6 is a 14-inch section to be used instead of Plan No. 5 when traffic conditions justify the use of a larger tie plate.

All designs have either double or single shoulder except Plan No. 6, which has double shoulder only.

All designs are canted approximately 1 to 40.

The designs with inclined ends provide for either rolled crown or pressed camber or no camber; those with flat ends have rolled crown only.

The bottom design is left optional with the purchaser, except that Plan No. 6 has flat bottom only.

The locations of spike holes are indicated, but other locations are optional with the purchaser.

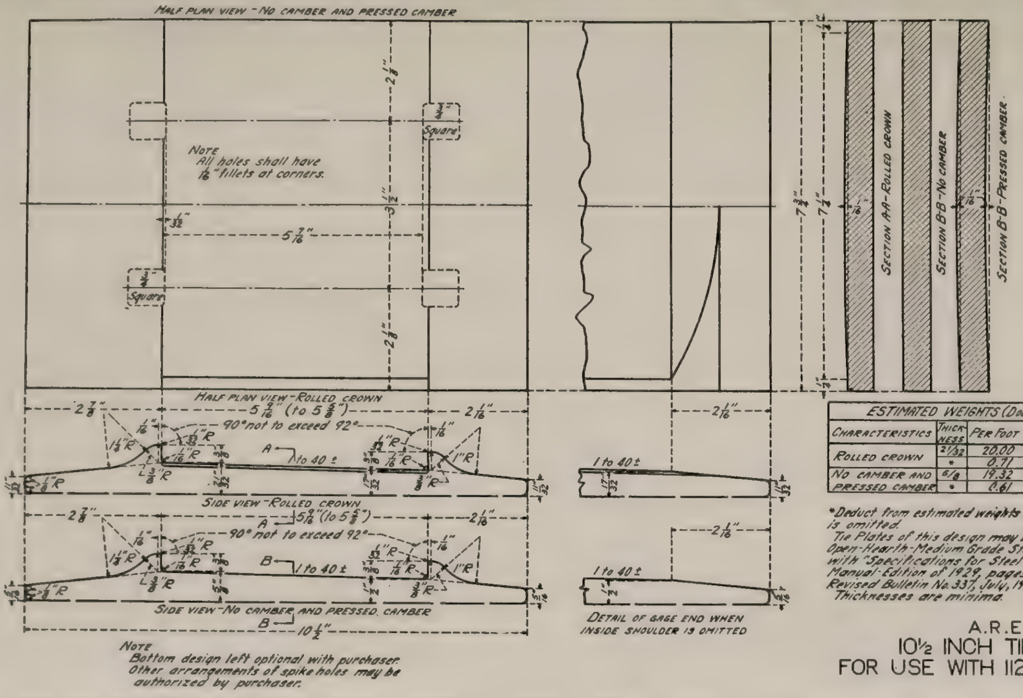
Thicknesses are the minimum which will give satisfactory service when manufactured in "medium grade" steel in accordance with current American Railway Engineering Association specifications. Increased thicknesses would be advantageous, but the Committee feels justified in presenting designs of minimum adequate thickness only.

In regard to presenting thinner designs of tie plates to be manufactured from higher strength steels, Dr. A. N. Talbot has advised the Committee that—

> "Stiffness is important to obtain intensity of pressures at the ends of the plates that do not vary much from the average pressure on the tie * * *
>
> Although the deflections of the plate are small, the depression of the wood by the load on the plate is also small,—of the order of 0.02 or 0.03-inch or less for a solid tie free from checks. * * *
>
> "For the same load and the same distribution over the plate, the deflection of the plate of Plan No. 2 is estimated to be nearly 50 per cent greater for a thickness of 21/32 inch than for 25/32 inch. This additional deflection interferes greatly with the desired distribution of pressure over the wood of the tie.
>
> * * *
>
> "It may be well to repeat that since the modulus of elasticity of two grades of steel is the same, the deflections of beams of the same thickness are equal when the loads and other conditions are the same, and also that changes of thickness apply equally to two grades of steel.
>
> * * *
>
> "The thickness of the plate and its resulting stiffness may govern even when the strength of the plate is otherwise adequate."

In view of the preceding the Committee is recommending one series of designs only, which are suitable for manufacture in "medium grade" steel.

Plans Nos. 1 to 6, inclusive are submitted herewith.


HALF PLAN VIEW - NO CAMBER AND PRESSED CAMBER
Note
All holes shall have 1/16" fillets at corners.
3/4" Square
2 1/8"
3 1/2"
5 7/16"
1/32"
HALF PLAN VIEW - ROLLED CROWN
2 7/8"
5 9/16" (to 5 5/8")
2 1/16"
90° not to exceed 92°
1 1/4"R
1"R
1/16"R
3/8"R
1/8"R
7/16"R
A
1 to 40 ±
SIDE VIEW - ROLLED CROWN
B
1 to 40 ±
SIDE VIEW - NO CAMBER AND PRESSED CAMBER
10 1/2"
7 3/4"
7 1/4"
1/4"
DETAIL OF GAGE END WHEN INSIDE SHOULDER IS OMITTED
SECTION A-A - ROLLED CROWN
SECTION B-B - NO CAMBER
SECTION B-B - PRESSED CAMBER

NOTE
Bottom design left optional with purchaser.
Other arrangements of spike holes may be authorized by purchaser.

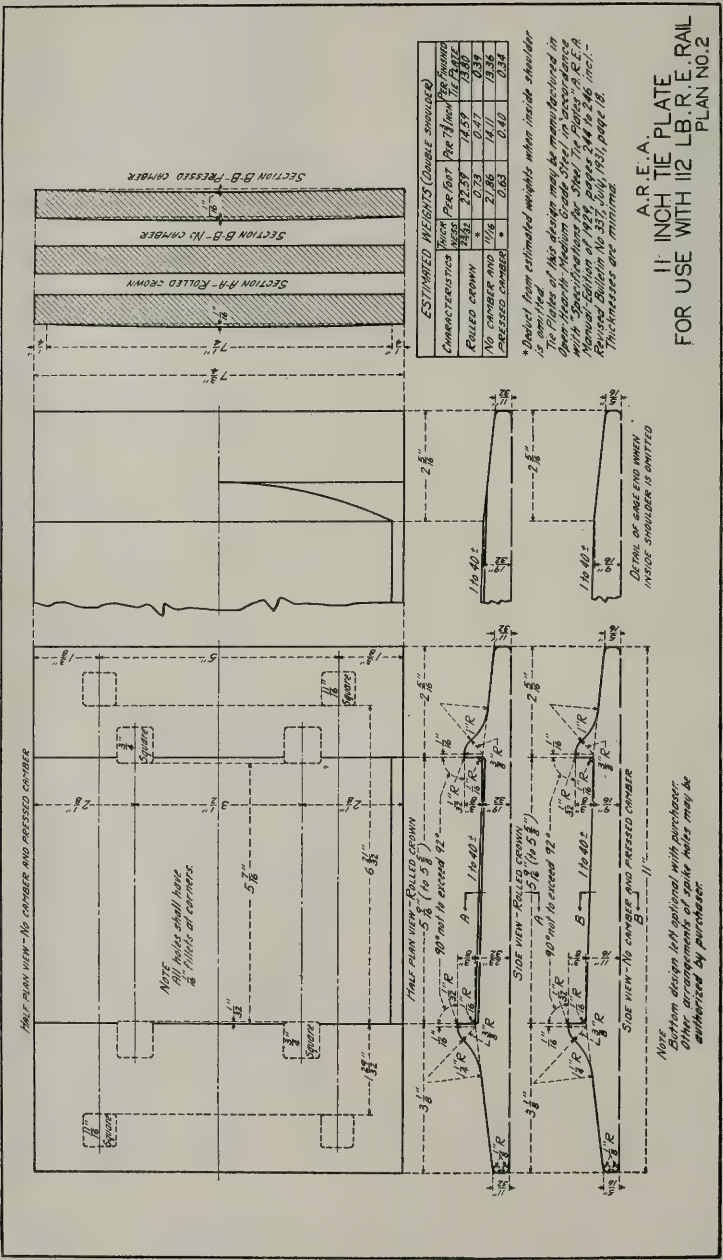
ESTIMATED WEIGHTS (DOUBLE SHOULDER)				
CHARACTERISTICS	THICKNESS	PER FOOT	PER 7¾ INCH	PER FINISHED TIE PLATE
ROLLED CROWN	21/32	20.00	12.92	12.41
	*	0.71	0.46	0.37
NO CAMBER AND PRESSED CAMBER	5/8	19.32	12.48	12.00
	*	0.61	0.40	0.35

*Deduct from estimated weights when inside shoulder is omitted.

Tie Plates of this design may be manufactured in Open-Hearth-Medium Grade Steel in accordance with "Specifications for Steel Tie Plates" A.R.E.A. Manual-Edition of 1929, pages 244 to 246 incl.-Revised Bulletin No. 337, July, 1931, page 18.

Thicknesses are minima.

A.R.E.A.
10½ INCH TIE PLATE
FOR USE WITH 112 LB. R.E. RAIL
PLAN NO. 1


HALF PLAN VIEW - NO CAMBER AND PRESSED CAMBER
NOTE All holes shall have 1/16" fillets at corners.
11/16" Square
3/4" Square
HALF PLAN VIEW - ROLLED CROWN
SIDE VIEW - ROLLED CROWN
SIDE VIEW - NO CAMBER AND PRESSED CAMBER
90° not to exceed 92°
1 to 40 ±
DETAIL OF GAGE END WHEN INSIDE SHOULDER IS OMITTED
SECTION A-A - ROLLED CROWN
SECTION B-B - NO CAMBER
SECTION B-B - PRESSED CAMBER
7 3/4"
11"
5 7/16"
6 21/32"
1 29/32"
2 5/16"
3 1/8"
NOTE Bottom design left optional with purchaser. Other arrangements of spike holes may be authorized by purchaser.

ESTIMATED WEIGHTS (DOUBLE SHOULDER)

CHARACTERISTICS	THICKNESS	PER FOOT	PER 7¾ INCH	PER FINISHED TIE PLATE
ROLLED CROWN	23/32	22.59	14.59	13.80
	*	0.73	0.47	0.39
NO CAMBER AND PRESSED CAMBER	11/16	21.86	14.11	13.36
	*	0.63	0.40	0.34

*Deduct from estimated weights when inside shoulder is omitted.

Tie Plates of this design may be manufactured in Open-Hearth-Medium Grade Steel in accordance with "Specifications for Steel Tie Plates" A.R.E.A. Manual-Edition of 1929, pages 244 to 246 incl.- Revised Bulletin No 337, July, 1931, page 18.

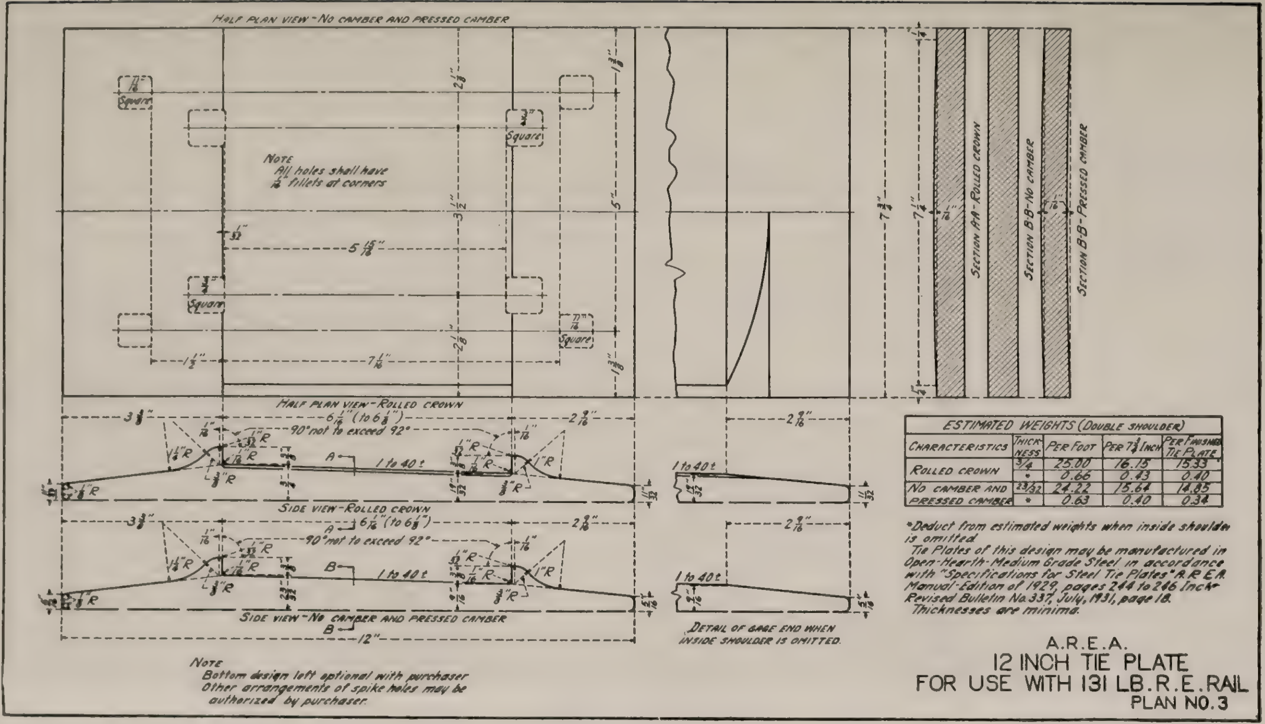
Thicknesses are minima.

A.R.E.A.

11 INCH TIE PLATE

FOR USE WITH 112 LB. R.E. RAIL

PLAN NO. 2


HALF PLAN VIEW - NO CAMBER AND PRESSED CAMBER
HALF PLAN VIEW - ROLLED CROWN
SIDE VIEW - ROLLED CROWN
SIDE VIEW - NO CAMBER AND PRESSED CAMBER
SECTION A-A - ROLLED CROWN
SECTION B-B - NO CAMBER
SECTION B-B - PRESSED CAMBER
DETAIL OF GAGE END WHEN INSIDE SHOULDER IS OMITTED.
Square
5 15/16"
7 1/16"
1 1/2"
2 1/8"
3 1/2"
1 3/8"
5"
7 3/4"
7 1/4"
6 1/16" (to 6 1/8")
90° not to exceed 92°
1 to 40
2 9/16"
3 3/8"
12"
1" R
1/8" R
3/8" R
A
B

NOTE
All holes shall have 1/16" fillets at corners

NOTE
Bottom design left optional with purchaser
Other arrangements of spike holes may be authorized by purchaser.

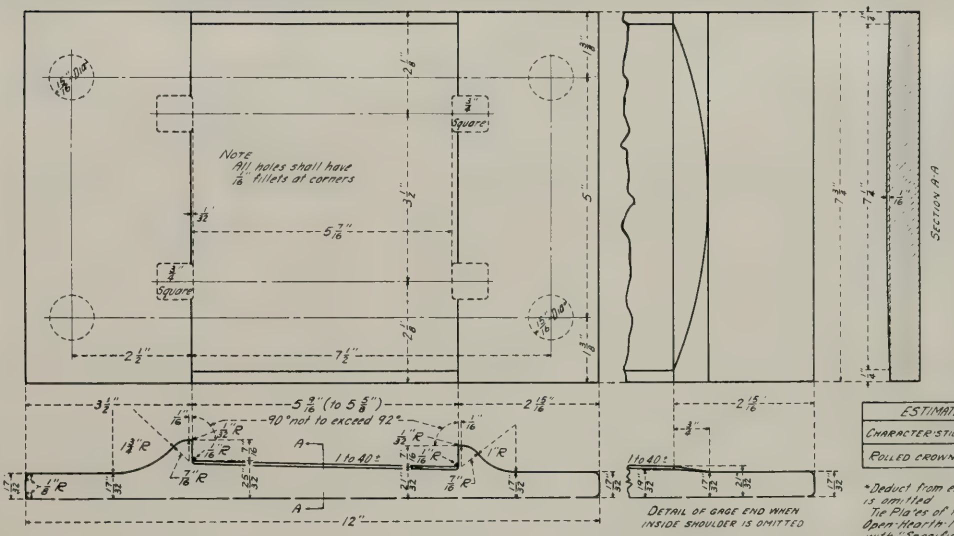
ESTIMATED WEIGHTS (DOUBLE SHOULDER)				
CHARACTERISTICS	THICKNESS	PER FOOT	PER 7¾ INCH	PER FINISHED TIE PLATE
ROLLED CROWN	3/4	25.00	16.15	15.33
	*	0.66	0.43	0.40
NO CAMBER AND PRESSED CAMBER	23/32	24.22	15.64	14.85
	*	0.63	0.40	0.34

*Deduct from estimated weights when inside shoulder is omitted.

Tie Plates of this design may be manufactured in Open-Hearth-Medium Grade Steel in accordance with "Specifications for Steel Tie Plates" A.R.E.A. Manual-Edition of 1929, pages 244 to 246 Inc.—Revised Bulletin No. 337, July, 1931, page 18.

Thicknesses are minima.

A.R.E.A.
12 INCH TIE PLATE
FOR USE WITH 131 LB. R.E. RAIL
PLAN NO. 3



NOTE
All holes shall have 1/16" fillets at corners

NOTE
Bottom design left optional with purchaser
Other arrangements of spike holes may be authorized by purchaser

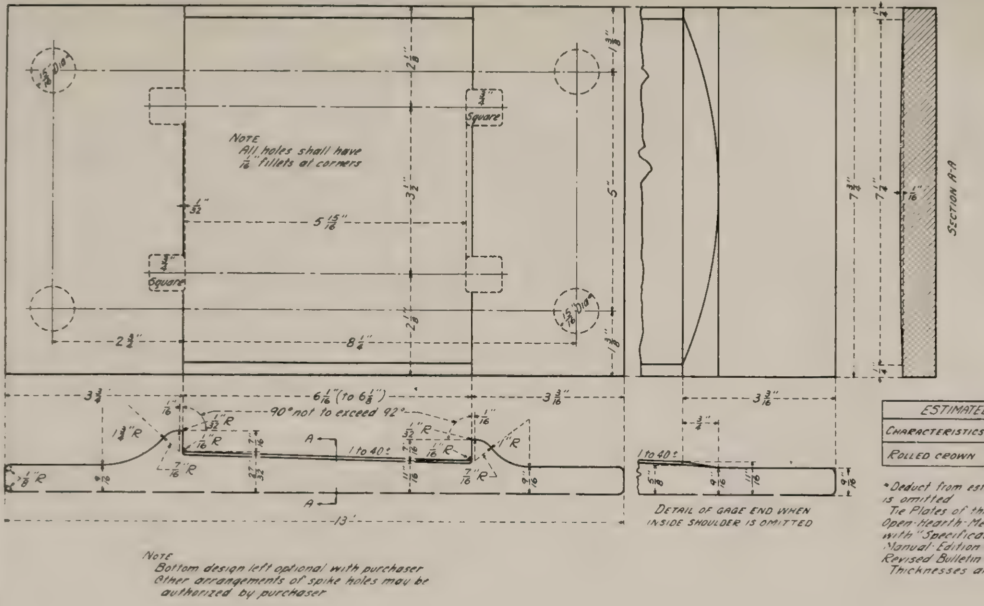
ESTIMATED WEIGHTS (DOUBLE SHOULDER)				
CHARACTERISTICS	THICKNESS	PER FOOT	PER 7 3/4 INCH	PER FINISHED TIE PLATE
ROLLED CROWN	25/32	27.44	17.72	16.68
	*	0.93	0.60	0.50

*Deduct from estimated weights when inside shoulder is omitted

Tie Plates of this design may be manufactured in Open-Hearth-Medium Grade Steel in accordance with "Specifications for Steel Tie Plates" A R E A Manual-Edition of 1929, pages 244 to 246 incl-Revised Bulletin No 337, July, 1931, page 18

Thicknesses are minima

A.R.E.A.
12 INCH TIE PLATE
FOR USE WITH 112 LB. R.E. RAIL
PLAN NO. 4



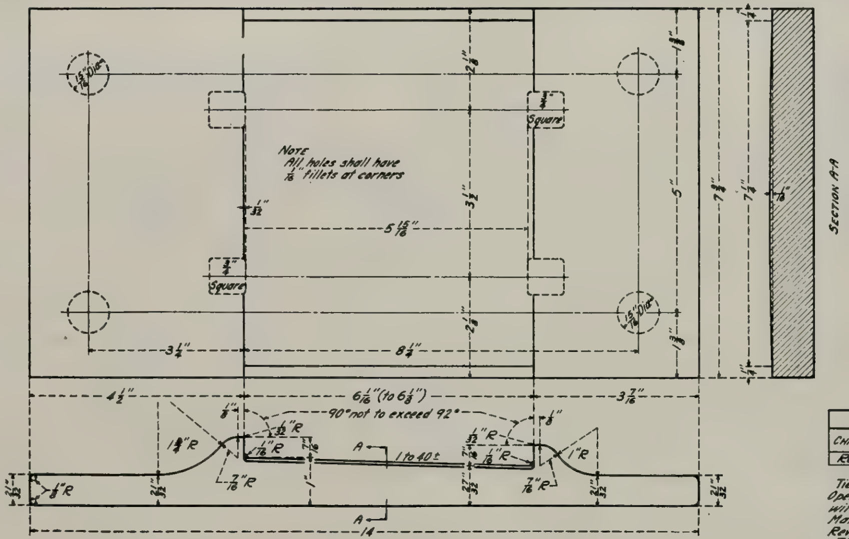
ESTIMATED WEIGHTS (DOUBLE SHOULDER)				
CHARACTERISTICS	THICKNESS	PER FOOT	PER $7\frac{3}{4}$ INCH	PER FINISHED TIE PLATE
ROLLED CROWN	27/32	31.29	20.21	19.12
	*	0.93	0.60	0.50

*Deduct from estimated weights when inside shoulder is omitted

Tie Plates of this design may be manufactured in Open-Hearth-Medium Grade Steel in accordance with "Specifications for Steel Tie Plates" A.R.E.A. Manual-Edition of 1929, pages 244 to 246 Incl.-Revised Bulletin No. 337, July, 1931, page 18.

Thicknesses are minima

A.R.E.A.
13 INCH TIE PLATE
FOR USE WITH 131 LB. R.E. RAIL
PLAN NO. 5



Note
Other arrangements of spike holes may be authorized by purchaser.

ESTIMATED WEIGHTS				
Characteristics	Thickness	Per Foot	Per 7¾ Inch	Per Finished Tie Plate
Rolled Crown	1	39.65	25.61	24.32

Tie Plates of this design may be manufactured in Open-Hearth-Medium Grade Steel in accordance with "Specifications for Steel Tie Plates" A.R.E.A. Manual-Edition of 1929, pages 244 to 246 incl.-Revised Bulletin No. 337, July, 1931, page 18.

Thicknesses are minima.

A.R.E.A.
14 INCH TIE PLATE
FOR USE WITH 131 LB. R.E. RAIL
PLAN NO. 6

Conclusions

The Committee recommends:

That Plans Nos. 1 to 6, inclusive, be adopted as recommended practice and published in the Manual.

Appendix G

(7) PRACTICABILITY OF USING REFLEX UNITS FOR SWITCH LAMPS AND TARGETS

H. D. Knecht, Chairman, Sub-Committee; F. J. Bishop, J. J. Desmond, F. J. Jerome, S. N. Mills, J. B. Strong.

The Committee reports progress, but is not sufficiently prepared to present a report this year. It is recommended that the subject be continued.

Appendix H

(8) RECLAMATION OF SERVICEABLE MATERIALS FROM SCRAP AND RETIRED MAINTENANCE OF WAY AND STRUCTURES MACHINES, TOOLS, AND APPLIANCES

C. J. Geyer, Chairman.

This subject is being handled by a general committee appointed by the different Divisions of the Association of American Railroads. The Chairman of the Track Committee represents the Engineering Division on the general committee. There have been two meetings of this general committee this year and progress is being made on the subject.

Appendix I

(9) DETERMINATION OF THE LIMITING RELATIVE POSITIONS OF THE ABUTTING RAILS OF FIXED AND DRAWSPANS OF BRIDGES AND PROPER TOLERANCES

L. H. Bond, Chairman, Sub-Committee; F. J. Bishop, F. H. Masters, C. J. Rist, E. D. Swift, M. J. T. Zeeman.

The Sub-Committee made report as information last year and recommended that the subject be discontinued. Since that time the collaborating committees have raised some question on the report and the Track Committee is endeavoring to adjust the differences which exist.

REPORT OF COMMITTEE XVII—WOOD PRESERVATION

C. F. Ford, *Chairman;*
Wm. G. Atwood,
Z. M. Briggs,
Walter Buehler,
C. S. Burt,
G. B. Campbell,
H. R. Condon,
C. C. Cook,
E. A. Craft,
H. R. Duncan,
E. B. Fulks,
W. R. Goodwin,
L. B. Holt,
G. R. Hopkins,
H. E. Horrocks,
R. S. Hubley,
R. P. Hughes,
M. F. Jaeger,
Dr. A. L. Kammerer,
A. M. Knowles,
A. J. Loom,
G. P. MacLaren,
F. D. Mattos,
R. S. Belcher, *Vice-Chairman;*
L. J. Reiser,
Dr. Henry Schmitz,
L. B. Shipley,
O. C. Steinmayer,
G. C. Stephenson,
T. H. Strate,
W. A. Summerhays,
C. Marshall Taylor,
Dr. Hermann von Schrenk,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual (Appendix A).

(2) Service Test Records for Treated Ties (Appendix B). Progress report.

(3) Piling used for Marine Construction (Appendix C). Progress report.

(4) Effect of preservative treatment by use of—(a) creosote and petroleum, (b) zinc chloride and petroleum. Progress in study—no report.

(5) Destruction by termites and possible ways of prevention (Appendix D). Progress report.

(6) Effect on preservative in treated ties in track due to blowing off locomotives on line of road, collaborating with Committees XIII—Water Service, Fire Protection and Sanitation; XXII—Economics of Railway Labor, and XXVII—Maintenance of Way Work Equipment (Appendix E). Progress report.

(7) Incising of all forest products material. Progress in study—no report.

(8) Investigations being made for the determination of toxicity value of creosote and creosote mixtures. Progress in study—no report.

The Committee on Wood Preservation,
C. F. Ford, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

O. C. Steinmayer, Chairman, Sub-Committee: R. S. Belcher, Walter Buehler, C. S. Burt, H. R. Duncan, E. B. Fulks, H. E. Horrocks, M. F. Jaeger, F. D. Mattos, L. C. Shipley, G. C. Stephenson, Dr. Hermann von Schrenk.

(a) SPECIFICATIONS FOR CREOSOTE

For several years now your Committee has been investigating the value of the float test in the present Creosote Specifications—both in creosote as it is received directly from tar works and the creosote after it has been in use for some time in treating operations, more particularly in connection with the value of the float test serving its original purpose in detecting tar contamination. Information has been presented that the test not only fails frequently to detect known additions of tar, but also discriminates occasionally against known distillate oils. Moreover, in some cases, oils failing to meet the float test requirement can be adjusted to meet this requirement by the addition of tar.

Bulletin 383, January, 1936.

Your Committee recommends the withdrawal of the float test requirement in the Standard Specifications for Creosote and Creosote Coal-Tar Solution by the elimination of Paragraph Six.

Similar action is being taken by the American Wood Preservers' Association.

(b) DEFINITIONS OF TERMS USED IN WOOD PRESERVATION

Your Committee has gone over the various definitions of terms as they now appear in the Manual and is of the opinion that the following can be deleted without causing confusion in the mind of the readers when such terms are encountered in the various standards. Some of the terms as they now appear are simply repetitions, some are relatively unimportant, others are explained in the text of the Manual matter.

Adzing.
Air-Seasoned.
Anthracene.
Artificial Seasoning.
Bored Tie.
Brush Treatment.
Butt Treatment.
C Iron.
Carbon, Free.
Charging Tank.
Coal Tar.
Coal Gas Tar (Gas House Tar).
Coefficient of Expansion.
Coke-Oven Tar.
Coke Residue.
Coke Test.
Copper Sulphate.
Corrosive Sublimate.
Creosote, Distillate.
Cylinder, Treating.
Distillation Test.
Drain Tank.
Empty Cell Treatment.
Emulsion.
Extraction Flask.
Final Retention.
Final Vacuum.
Flask, Distilling.
Flask, Extraction.
Float Test.
Full Cell Treatment.
Gas-house Tar.
Gravity.
Gross Absorption.
Humidity.
Humidity, Relative.
Hydrometer.
Hygrometer.
Hygroscopic Moisture.
Incipient Decay.
Increment Borer.
Initial Absorption.
Initial Air.
Initial Vacuum.
Kiln Dried.
Marine Borers.
Measuring Tank.
Mercuric Chloride.
Mixing Tank.
Mycelium.
Nail, Dating.
Naphthalene.
Net Absorption.
Non-Pressure Treatment.
Oil Seasoning.
Open Tank Treatment
Preliminary Air.
Preliminary Vacuum.
Pressure Treatment.
Pump, Pressure.
Pump, Vacuum.
Pycnometer.
Recording Gages.
Refusal Treatment.
Relative Humidity.
S Iron.
Seasoned, Air.
Sodium Fluoride.
Specific Gravity.
Spray Treatment.
Steaming.
Surface Treatment.
Thief, Sample.
Tie Plug
Viscosimeter.
Viscosity.
Volumetric Absorption
Water-Free Oil.
Water-Gas Tar.
Wet Oil.
Z Iron.
Zinc Chloride.

Editorial changes have been made in the definition of Creosote; Creosote-Coal Tar Solution; Distillate Creosote; Distillate Oil, and Test, Float.

The definition for "Anti-Checking Iron" is revised in accordance with the following:

"A piece of flat iron, sharpened on one edge, used for driving into the end of a piece of timber to prevent checking and splitting, and bent to the shape of C, S or Z, and called C Iron, S Iron or Z Iron."

The definition for "Dating Nail" is to be changed to conform to the definition as it now appears under "Nail, Dating".

The words in the definition "Initial Air" are to be interchanged so that the term "Air, Initial" appears immediately preceding the term "Air, Preliminary".

The definition for the term "Treating Cylinder" should be altered to conform to that definition now given for the term "Cylinder, Treating".

The words "Same as Treating Cylinder" should be added to the definition for "Retort".

(c) SPECIFICATIONS FOR TREATING PROCESSES

The study which is being made towards a revision of the Specifications for Treating Processes has not progressed sufficiently at this time to make a definite recommendation.

Appendix B

(2) SERVICE TEST RECORDS FOR TREATED TIES

W. R. Goodwin, Chairman, Sub-Committee; Z. M. Briggs, G. B. Campbell, E. A. Craft, L. B. Holt, R. S. Hubley, A. J. Loom, R. P. Hughes, G. P. MacLaren, T. H. Strate, W. A. Summerhays.

The table of tie renewals per mile maintained on various roads has been revised to include data for 1934.

Reports of special test tracks are submitted on the following roads:

Baltimore and Ohio at Herring Run, Md., and Windsor–Blanchester, Ohio.

Chicago, Burlington and Quincy.

Chicago, Milwaukee, St. Paul and Pacific at Hartford, Wis., and Madison, Wis.

Interstate Public Service of Indiana.

Northern Pacific untreated white oak, creosoted western hemlock and creosoted tamarack.

The above information is offered as a progress report.

THE BALTIMORE AND OHIO RAILROAD COMPANY

Report of Herring Run, Md., Special Test Track—1934 Inspection

Age of Test, Twenty Years—Kind of Wood, Red Oak

Sec. No.	Tie Numbers	Process	Per Cu. Ft.	Ties Placed	Ties in Test	Removed to date		Average life to date of ties in test
						No.	Per Cent	
				Note	Note			
1	3— 300	Untreated		298	289	289	100.0	5.1
2	301— 600	Burnettizing	0.35 lb. Zinc Chl.	300	161	153	95.0	12.6
3	601— 900	Burnettizing	0.63 lb. Zinc Chl.	300	211	162	76.8	14.9
4	901—1200	Straight-Cr.	4.02 lb. Creosote	300	300	233	77.7	16.2
5	1201—1500	Straight-Cr.	9.78 lb. Creosote	300	300	74	24.7	19.3
6	1501—1650	Straight W. G. Tar Creo.	5.16 lb. W. G. Tar Cr.	150	150	108	72.0	16.7
7	1651—1800	Straight W. G. Tar Creo.	6.12 lb. W. G. Tar Cr.	150	150	111	74.0	16.9
8	1801—1950	Straight W. G. Tar Creo.	7.09 lb. W. G. Tar Cr.	150	150	128	85.3	15.0
9	1951—2100	Straight W. G. Tar Creo.	10.90 lb. W. G. Tar Cr.	150	150	118	78.7	16.2
10	0-212 Cull	Straight W. G. Tar Creo.	11.00 lb. W. G. Tar Cr.	212	211	172	81.5	14.8
11	2101—2400	Sodium Fluoride	0.41 lb. Sodium Fluoride	300	300	295	98.3	14.5
12	2401—2700	Card	0.63 lb. Zinc Chlor. 0.76 lb. Creosote	300	300	297	99.0	13.2
13	2701—3000	Card	0.69 lb. Zinc Chlor. 1.35 lb. W. G. Tar Cr. 0.37 lb. Creosote	300	300	254	84.7	15.7
14	3001—3300	Card	0.5 lb. Zinc Chlor. 2.0 lb. Creosote*	300	288	285*	99.0	* 13.1

Note—The difference between "Ties Placed" and "Ties in Test" is due to elimination from test of ties account of removals from derailments and installation of switches.

*—This group installed 9 months (.75 year) after other ties in this test.

Item	Annual Average
Traffic-Gross Tons (Thousands)	16,855
Temperature—Mean January	35.7
Fahrenheit—Mean July	77.6
Highest Annual	99.6
Lowest Annual	8.0
Rainfall—Inches	41.3

THE BALTIMORE AND OHIO RAILROAD COMPANY

Report on Windsor—Blanchester, Ohio, Special Test Tracks—1934 Inspection

AGE OF TIE TEST—24 YEARS

Treatment and Kind of Wood	Ties Placed	Ties in Test	Removed to date		Ave. Life to Date of Ties in Test
			No.	Per cent	
	Note	Note			
UNTREATED					
White Oak	757	757	749	98.9	10.2
STRAIGHT CREOSOTE					
Red Oak	873	820	136	16.6	23.2
*Other Woods	252	252	123	48.8	19.1
CARD PROCESS					
Red Oak	1125	1125	590	52.4	20.4
*Other Woods	1219	1206	833	69.1	18.0
TIMBER ASPHALT					
Red Oak	984	969	963	99.4	10.7

Note—The difference between "Ties Placed" and "Ties in Test" is due to elimination from test of ties account of removals from derailments.

*Other Woods—Beech, Hard Maple, Gum and Elm.

TRAFFIC AND CLIMATE

Item		Annual Average
Traffic—Gross Tons (Thousands)		5,039
Temperature	—Mean January	31.4
(Fahrenheit)	—Mean July	74.5
	—Highest Annual	96.5
	—Lowest Annual	5.7
Rainfall	0 Inches	40.8

KS

									nt 'ed nt r 's	Actual average year's life to date
										20.5
										17.5
										14.9
										5.8
										19.7
										17.7
										17.2
									---	5.3
										22.7
										19.3
										15.7
										5.4
										21.0
										17.6
										14.4
									-	3.6
										10.2
									---	--------
									---	--------
										10.2
										21.4
										17.3
									---	--------
									---	3.5
										19.2
										17.9
										14.7
										7.5
										21.9
										19.5
										16.0
										5.9
										18.1
										15.6
										15.3
										5.3
										20.3
										15.8
										17.3
									--	5.5
										17.7
Card	949	685	27	45	18.6	386	336	25	62	15.3
Burnett	128	127	73	26	12.3	72	72	46	54	12.0
Untreated	157	157	99	1	5.5	91	91	100	---	1.8

COMMITTEE 7 A.W.R.A.
(XVII) A.R.E.A.

CROSS TIE RENEWALS PER MILE OF ALL TRACK MAINTAINED 1911-1940

AT&SF	B&O	CB&Q	C&EI	CCC&StL	CMStP&P	CRI&P	DL&W	GT NORTHERN	ILLS CENTRAL	YEAR	K C SOU	LEHIGH VALLEY	MICH CENT	MK&T	MONON CI&L	NYC (EAST)	NYC (WEST)	NOR PACIFIC	PENNA	SOO LINE (SYSTEM)	YEAR	SOUTHERN PAC (ATLANTIC SYST.)	SOUTHERN PAC (PACIFIC SYST.)	UNION PACIFIC	C R R of N J	READING	BOSTON & MAINE	C & O				TOTALS FOR ALL ROADS
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]

⊗ TANGENT ONLY

SUMMARY OF 1934 INSPECTION OF CROSS-TIE TEST TRACKS C. B. & Q. R. R. RESULTS OF 25 YEARS' SERVICE

	LINES EAST					LINES WEST				
Process	Total placed	Total removed to date	Per cent removed account decay	Per cent removed account other causes	Actual average year's life to date	Total placed	Total removed to date	Per cent removed account decay	Per cent removed account other causes	Actual average year's life to date
Creosote	2,046	1,004	16	33	21.9	1,236	670	15	39	20.5
Card	10,242	8,150	29	50	18.3	5,591	4,762	32	53	17.5
Burnett	1,578	1,487	51	43	15.9	910	888	48	49	14.9
Untreated	2,046	2,045	89	10	5.4	1,226	1,226	91	9	5.8
ASH TIES										
Creosote	19	18	32	63	16.6	15	11	20	53	19.7
Card	289	241	17	67	18.4	103	87	22	62	17.7
Burnett	16	15	50	44	18.3	15	15	47	53	17.2
Untreated	70	70	99	1	5.1	46	46	100	--------	5.3
BEECH TIES										
Creosote	321	85	7	20	23.4	163	54	8	25	22.7
Card	807	729	42	48	17.4	418	381	39	52	19.3
Burnett	210	199	52	43	15.5	105	102	57	40	15.7
Untreated	134	134	98	2	4.6	74	74	93	7	5.4
BIRCH TIES										
Creosote	75	52	49	20	22.0	59	29	14	36	21.0
Card	715	579	36	45	17.5	360	314	33	54	17.6
Burnett	73	73	48	52	12.9	30	30	47	53	14.4
Untreated	139	139	99	1	3.6	78	78	100	----	3.6
CHESTNUT TIES										
Card	164	164	18	82	10.1	89	89	9	91	10.2
Creosote	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Burnett	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Untreated	169	169	28	72	9.4	90	90	22	78	10.2
COTTONWOOD TIES										
Creosote	88	31	1	34	22.9	45	16	13	22	21.4
Card	296	225	26	50	18.6	160	130	26	56	17.3
Burnett	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
Untreated	56	56	95	5	2.6	30	30	100	--------	3.5
CYPRESS TIES										
Creosote	25	8	4	28	23.6	29	22	41	34	19.2
Card	409	320	10	68	18.8	254	215	24	60	17.9
Burnett	25	17	------	68	20.9	30	30	50	50	14.7
Untreated	135	132	78	20	8.8	90	90	89	11	7.5
ELM TIES										
Creosote	208	94	19	26	22.4	119	44	9	27	21.9
Card	594	411	24	45	20.1	371	265	27	45	19.5
Burnett	224	201	43	47	18.5	73	69	59	36	16.0
Untreated	113	113	91	9	4.8	78	78	96	4	5.9
HEMLOCK TIES										
Creosote	136	102	26	49	19.1	99	80	22	59	18.1
Card	816	697	27	58	17.8	488	450	38	55	15.6
Burnett	125	113	45	46	17.0	87	79	33	57	15.3
Untreated	112	112	100	--------	4.7	78	78	99	1	5.3
HICKORY TIES										
Creosote	10	5	10	40	23.2	15	8	13	40	20.3
Card	185	174	30	64	16.2	105	98	42	51	15.8
Burnett	9	7	11	67	21.0	15	15	53	47	17.3
Untreated	65	65	89	11	5.5	45	45	100	------	5.5
PINE TIES—LOBLOLLY SAP										
Creosote	145	71	8	41	22.0	72	51	18	53	17.7
Card	949	685	27	45	18.6	386	336	25	62	15.3
Burnett	128	127	73	26	12.3	72	72	46	54	12.0
Untreated	157	157	99	1	5.5	91	91	100	----	4.8

SUMMARY OF 1934 INSPECTION OF CROSS-TIE TEST TRACKS C. B. & Q. R. R. RESULTS OF 25 YEARS' SERVICE

Process	Lines East					Lines West				
	Total placed	Total removed to date	Per cent removed account decay	Per cent removed account other causes	Actual average year's life to date	Total placed	Total removed to date	Per cent removed account decay	Per cent removed account other causes	Actual average year's life to date
Hard Maple Ties										
Creosote	82	42	37	15	22.7	34	18	9	44	21.1
Card	561	396	34	37	19.7	272	234	36	50	18.8
Burnett	50	45	44	46	19.4	15	15	87	13	16.7
Untreated	77	77	98	2	4.3	45	45	100	--------	5.3
Soft Maple Ties										
Creosote	139	108	38	39	18.9	63	32	22	29	20.3
Card	462	394	46	39	16.6	264	206	27	52	18.2
Burnett	125	125	64	36	13.4	57	57	39	61	13.6
Untreated	82	82	99	1	3.4	43	43	95	5	4.0
White Oak Ties										
Creosote	25	9	4	32	24.4	15	11	27	47	19.0
Card	234	217	38	55	17.1	152	143	30	64	16.8
Burnett	28	28	60	40	17.4	15	15	40	60	15.3
Untreated	81	81	88	12	10.8	44	44	81	19	11.7
Red Oak Ties										
Creosote	165	63	3	35	22.8	120	68	13	43	21.1
Card	776	595	21	55	19.5	510	486	34	61	17.0
Burnett	158	150	52	43	17.1	116	112	43	53	15.2
Untreated	129	129	96	4	5.1	75	75	93	7	5.7
Pin Oak Ties										
Creosote	189	57	3	27	23.1	133	50	8	29	22.8
Card	512	349	19	49	20.7	321	274	26	60	19.3
Burnett	23	17	39	35	21.7	44	44	32	68	15.9
Untreated	81	81	96	4	6.4	45	45	98	2	6.2
Poplar Ties										
Creosote	50	24	12	36	22.1	30	27	17	73	16.9
Card	396	372	41	53	15.3	253	233	42	51	15.2
Burnett	50	48	40	56	14.3	30	30	57	43	13.0
Untreated	81	81	94	6	5.1	45	45	96	4	5.6
Red Gum Ties										
Creosote	89	59	29	37	19.5	48	31	27	38	17.8
Card	429	336	37	42	18.5	233	165	38	33	18.9
Burnett	75	74	66	33	11.6	43	43	74	26	12.4
Untreated	98	98	97	3	3.8	54	54	98	2	4.6
Sycamore Ties										
Creosote	75	34	28	17	22.1	15	2	--------	13	23.1
Card	399	266	40	26	18.7	121	112	64	29	14.4
Burnett	75	74	70	29	13.7	15	15	80	20	13.5
Untreated	81	81	98	2	2.9	50	50	96	4	3.9
Tamarack Ties										
Creosote	106	83	10	68	20.7	108	83	14	63	18.4
Card	813	746	21	71	17.9	494	444	32	58	17.1
Burnett	108	99	38	54	17.9	107	104	32	65	16.0
Untreated	98	98	96	4	4.9	77	77	99	1	5.3
Tupelo Gum Ties										
Creosote	99	59	21	38	20.7	54	33	20	41	19.2
Card	436	254	18	41	20.8	237	100	20	22	22.4
Burnett	76	75	47	51	15.2	41	41	61	39	14.0
Untreated	88	88	98	2	3.0	48	48	98	2	4.4

CONDITION OF EXPERIMENTAL TIES IN THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILWAY TEST TRACK NEAR HARTFORD, WIS., AFTER ABOUT 23¾ YEARS SERVICE

Ties set October 1911 — Ties inspected June 1935

Preservative	Process	Tie plates	Average absorption	Ties in test	Good		Splitting		Decaying		Removed			
											Mainly for decay		For causes other than decay[a] and unknown causes[b]	
					No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent
			Lbs. per cu. ft.											
CHESTNUT														
Zinc chloride[3]	Burnett[c]	Flat	12.5[f]	10	------	--------	------	--------	------	--------	4	40.0	6	60.0
Zinc chloride[4]	Burnett[c]	Ribbed	12.5[f]	13	------	--------	------	--------	------	--------	6	46.1	7	53.9
MAPLE														
Creosote	Full cell	None	10.7	50	6	12.0	29	58.0	15	30.0	------	--------	------	--------
Creosote	Full cell	Flat	12.2	49	8	16.3	38	77.6	3	6.1	------	--------	------	--------
Creosote	Rueping	Flat	5.0	50	8	16.0	35	70.0	7	14.0	------	--------	------	--------
Creosote	Rueping	None	4.8	50	5	10.0	37	74.0	8	16.0	------	--------	------	--------
20% creo., 80% zinc chloride	Card	None	14.7[e]	50	6	12.0	27	54.0	15	30.0	2	4.0	------	--------
20% creo., 80% zinc chloride	Card	Flat	17.3[e]	50	1	2.0	30	60.0	16	32.0	2	4.0	1	2.0
Semi-refined paraffin oil	Full cell	Flat	11.1	50	------	--------	31	62.0	16	32.0	1	2.0	2	4.0
Semi-refined paraffin oil	Full cell	None	14.3	49	------	--------	38	77.6	10	20.4	1	2.0	------	--------
Zinc chloride-creosote	Two movement	Flat	16.4[d]	50	2	4.0	22	44.0	20	40.0	4	8.0	2	4.0
Zinc chloride-creosote	Two movement	None	15.1[d]	50	2	4.0	9	18.0	19	38.0	18	36.0	2	4.0
Zinc chloride	Burnett	None	20.1[j]	49	------	--------	------	--------	8	16.3	20	40.8	21	42.9
Zinc chloride	Burnett	Flat	21.1[i]	50	------	--------	------	--------	29	58.0	14	28.0	7	14.0
Untreated[5]	----------------	None	--------	50	------	--------	------	--------	------	--------	50	100.0	------	--------
Untreated[6]	----------------	Flat	--------	50	------	--------	------	--------	------	--------	50	100.0	------	--------

[a] Rail cutting, splitting, etc.

[b] Ties not available for examination after removal to determine the cause of removal.

[c] Obtained from regular stock of C. M. St. P. & P. Ry.

[f] 4 per cent zinc chloride solution.

[e] Emulsion of 80 parts of 3 per cent zinc chloride solution and 20 parts of creosote by volume at approximately 70° Fahr.

[d] 3 per cent chloride solution plus creosote. Treatment consisted of bath in hot creosote for 30 minutes at atmospheric pressure followed by pressure treatment with 3 per cent zinc chloride solution.

[i] 2½ per cent zinc chloride solution.

[3] Average life 15.6 years.

[4] Average life 13.4 years.

[5] Average life 6.4 years.

[6] Average life 7.8 years.

Condition of Experimental Black and Red Oak Ties in the Tracks of the Public Service Company of Indiana, Formerly the Interstate Public Service Company, After About 25¾ Years Service

Ties set September 1909 Ties inspected June 1935

Preservative	Approximate average absorption	Number of ties in test	Good		Splitting		Decaying		Removed			
									Mainly for decay		For causes other than decay[1] and unknown causes[2]	
			No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent
	Lbs. per cu. ft.											
Coal tar creosote	14	99	-----	-----	40	40.4	33	33.3	5	5.1	21	21.2
Coal tar creosote	12	60	-----	-----	29	48.4	14	23.3			17	28.3
Coal tar creosote	7 to 8	430	7	1.6	104	24.2	48	11.2	44	10.2	227	52.8
Creosote and zinc chloride[3]	Creo. 3-4 ZnCl$_2$ .45-.55	204	-----	-----	3	1.5	11	5.4	59	28.9	131	64.2
Asphaltic crude oil	Indeterminate	182[4]	-----	-----	1	0.5	1	0.5	155	85.2	25	13.8

[1] Rail cutting, splitting, etc.
[2] Information on cause of removal not available.
[3] Two movement treatment—creosote treatment followed by treatment with 4½ per cent zinc chloride solution.
[4] Average life—13.3 years. Value based on 180 removals.

Condition of Experimental Ties in the Chicago, Milwaukee, St. Paul and Pacific Railway Test Track Near the Fair Grounds, Madison, Wisconsin

Results of September, 1935 Inspection

Tie numbers	Species	Preservative	Average absorption	Ties in test	Years service	Good		Splitting		Decaying		Removed			
												Mainly for decay		For causes[a] other than decay	
						No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent
			Lbs. per cu. ft.	No.	No.										
370–398	Douglas fir[b]	Creosote	11.50	29	18	25	86.3	2	6.9	-----	-----	1	3.4	1	3.4
400–599	Red oak	Zinc chloride	0.55	166	19	1	0.6	-----	-----	34	20.5	126	75.9	5	3.0
600–699	Red oak	25% creo. and 75% gas oil	10.20	75	19	27	36.0	34	45.4	7	9.3	3	4.0	4	5.3
700–798	Red oak	10% creo. and 90% gas oil	10.00	98	19	39	39.8	38	38.8	16	16.3	1	1.0	4	4.1
1–42	Douglas fir[b]	Untreated[c]	-----	38	i	-----	-----	-----	-----	-----	-----	36	94.7	2	5.3
801–900	White oak	Untreated	-----	95	18	-----	-----	-----	-----	3	3.2	91	95.7	1	1.1
1001–1100	Red oak	Sodium fluoride	0.52	99	18	2	2.0	1	1.0	87	87.9	9	9.1	-----	-----
1101–1200	Red oak	Water gas tar	9.79	100	18	51	51.0	49	49.0	-----	-----	-----	-----	-----	-----
1201–1250	Western larch	Untreated	-----	44	18	-----	-----	-----	-----	1	2.3	42	95.4	1	2.3
1251–1300	Douglas fir[b]	Untreated	-----	48	18	4	8.3	-----	-----	8	16.7	33	68.8	3	6.2
1301–1405	Douglas fir[b]	Zinc chloride	0.52	105	16	4	3.8	13	12.4	42	40.0	27	25.7	19	18.1
1406–1500	Western larch	Zinc chloride	0.48	95	16	14	14.7	16	16.8	22	23.2	24	25.3	19	20.0
1501–1563	Red oak	50% C. T. creo. & 50% W. T. creo.	9.50	62	16	39	62.9	19	30.7	3	4.8	-----	-----	1	1.6
1564–1588	Slippery elm	50% C. T. creo. & 50% W. T. creo.	10.85	25	16	4	16.0	20	80.0	1	4.0	-----	-----	-----	-----
1589–1591, 1593–1598	Butternut	50% C. T. creo. & 50% W. T. creo.	9.00	8	16	-----	-----	4	50.0	4	50.0	-----	-----	-----	-----
1592	White oak	50% C. T. creo. & 50% W. T. creo.	7.30	1	16	1	100.0	-----	-----	-----	-----	-----	-----	-----	-----
1536, 1599, 1600	Cherry	50% C. T. creo. & 50% W. T. creo.	10.50	3	16	1	33.3	2	66.7	-----	-----	-----	-----	-----	-----
1601–1700	Red oak	Wood tar creosote	10.08	100	16	22	22.0	17	17.0	39	39.0	4	4.0	18	18.0
1701–1800	Red oak	Low temperature coal tar oil	10.30	100	14	50	50.0	49	49.0	-----	-----	-----	-----	1	1.0
1801–1900	Red oak	20% coal tar and 80%[d] low temp coal tar oil	10.50	100	14	52	52.0	48	48.0	-----	-----	-----	-----	-----	-----
1901–2000	Red oak	Vertical retort C. T. creo.	9.60	100	14	68	68.0	32	32.0	-----	-----	-----	-----	-----	-----
2001–2100	Red oak	Pintsch gas tar	10.50	100	14	58	58.0	41	41.0	1	1.0	-----	-----	-----	-----
2101–2480	Jack pine	Zinc chloride	0.52	381	8	289	75.9	36	9.4	56	14.7	-----	-----	-----	-----

[a] Rail cutting, splitting, etc.
[b] Western Washington and Oregon type.
[c] Switch ties—average life 6.5 years.
[d] Previously reported as 50% tar and 50% low temp. coal tar oil.

CONDITION OF EXPERIMENTAL TIES IN THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILWAY TEST TRACK NEAR HARTFORD, WIS., AFTER ABOUT 23¾ YEARS SERVICE

Ties set October 1911 — Ties inspected June 1935

Preservative	Process	Tie plates	Average absorption	Ties in test	Good		Splitting		Decaying		Removed			
											Mainly for decay		For causes other than decay[a] and unknown causes[b]	
					No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent
			Lbs. per cu. ft.											
					CHESTNUT									
Zinc chloride[3]	Burnett[e]	Flat	12.5[f]	10	......	......	......	......	......	......	4	40.0	6	60.0
Zinc chloride[4]	Burnett[e]	Ribbed	12.5[f]	13	......	......	......	......	......	......	6	46.1	7	53.9
					MAPLE									
Creosote	Full cell	None	10.7	50	6	12.0	29	58.0	15	30.0	......	......	......	......
Creosote	Full cell	Flat	12.2	49	8	16.3	38	77.6	3	6.1	......	......	......	......
Creosote	Rueping	Flat	5.0	50	8	16.0	35	70.0	7	14.0	......	......	......	......
Creosote	Rueping	None	4.8	50	5	10.0	37	74.0	8	16.0	......	......	......	......
20% creo., 80% zinc chloride	Card	None	14.7[c]	50	6	12.0	27	54.0	15	30.0	2	4.0	......	......
20% creo., 80% zinc chloride	Card	Flat	17.3[c]	50	1	2.0	30	60.0	16	32.0	2	4.0	1	2.0
Semi-refined paraffin oil	Full cell	Flat	11.1	50	......	......	31	62.0	16	32.0	1	2.0	2	4.0
Semi-refined paraffin oil	Full cell	None	14.3	49	......	......	38	77.6	10	20.4	1	2.0	......	......
Zinc chloride-creosote	Two movement	Flat	16.4[d]	50	2	4.0	22	44.0	20	40.0	4	8.0	2	4.0
Zinc chloride-creosote	Two movement	None	15.1[d]	50	2	4.0	9	18.0	19	38.0	18	36.0	2	4.0
Zinc chloride	Burnett	None	20.1[j]	49	......	......	......	......	8	16.3	20	40.8	21	42.9
Zinc chloride	Burnett	Flat	21.1[j]	50	......	......	......	......	29	58.0	14	28.0	7	14.0
Untreated[5]	......	None	......	50	......	......	......	......	......	......	50	100.0	......	......
Untreated[6]	......	Flat	......	50	......	......	......	......	......	......	50	100.0	......	......

[a] Rail cutting, splitting, etc.

[b] Ties not available for examination after removal to determine the cause of removal.

[e] Obtained from regular stock of C. M. St. P. & P. Ry.

[f] 4 per cent zinc chloride solution.

[c] Emulsion of 80 parts of 3 per cent zinc chloride solution and 20 parts of creosote by volume at approximately 70° Fahr.

[d] 3 per cent chloride solution plus creosote. Treatment consisted of bath in hot creosote for 30 minutes at atmospheric pressure followed by pressure treatment with 3 per cent zinc chloride solution.

[j] 2½ per cent zinc chloride solution.

[3] Average life 15.6 years.

[4] Average life 13.4 years.

[5] Average life 6.4 years.

[6] Average life 7.8 years.

CONDITION OF EXPERIMENTAL TIES IN THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILWAY TEST TRACK NEAR HARTFORD, WIS., AFTER ABOUT 23¾ YEARS SERVICE

Ties set October 1911 — Ties inspected June 1935

Preservative	Process	Tie plates	Average absorption	Ties in test	Good		Splitting		Decaying		Removed			
											Mainly for decay		For causes other than decay[a] and unknown causes[b]	
					No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent
			Lbs. per cu. ft.											
					RED OAK									
Creosote	Full cell	None	11.2	52	23	44.2	27	52.0	1	1.9	......	......	1	1.9
Creosote	Full cell	Flat	10.9	50	22	44.0	26	52.0	1	2.0		......	1	2.0
Creosote	Rueping	Flat	5.0	50	18	36.0	17	34.0	13	26.0	1	2.0	1	2.0
Creosote	Rueping	None	5.7	50	9	18.0	30	60.0	8	16.0	2	4.0	1	2.0
20% creo., 80% zinc chloride	Card	None	15.5[c]	50	5	10.0	12	24.0	29	58.0	1	2.0	3	6.0
20% creo., 80% zinc chloride	Card	Flat	15.2[c]	50	7	14.0	7	14.0	36	72.0	......	......	......	......
Semi-refined paraffin oil	Full cell	Flat	8.4	50	4	8.0	3	6.0	41	82.0	2	4.0	......	......
Semi-refined paraffin oil	Full cell	None	6.2	49	2	4.1	11	22.4	27	55.1	4	8.2	5	10.2
Zinc chloride-creosote	Two movement	Flat	14.7[d]	50	7	14.0	8	16.0	31	62.0	3	6.0	1	2.0
Zinc chloride-creosote	Two movement	None	16.0[d]	50	2	4.0	9	18.0	29	58.0	7	14.0	3	6.0
Zinc chloride	Burnett[e]	Flat	12.5[f]	157	......	......	......	......	18	11.5	100	63.7	39	24.8
Zinc chloride	Burnett[e]	Flat	12.5[f]	49	......	......	......	......	11	22.4	24	49.0	14	28.6
Zinc chloride	Burnett[e]	Ribbed	12.5[f]	53	......	......	......	......	13	24.5	22	41.5	18	34.0
Zinc chloride	Burnett	None	15.8[g]	50	......	......	......	......	34	68.0	13	26.0	3	6.0
Zinc chloride	Burnett	Flat	16.4[g]	50	......	......	......	......	39	78.0	6	12.0	5	10.0
Untreated[1]	......	None	......	50	......	......	......	......	......	......	50	100.0	......	......
Untreated[2]	......	Flat	......	50	......	......	......	......	......	......	50	100.0	......	......
					SPRUCE									
Mercuric chloride	Kyan	Flat	h	13	......	......	1	7.7	8	61.5	4	30.8	......	......
Mercuric chloride	Kyan	None	h	12	......	......	1	8.3	4	33.4	5	41.7	2	16.6

[a] Rail cutting, splitting, etc.

[b] Ties not available for, examination after removal to determine the cause of removal.

[c] Emulsion of 80 parts of 3 per cent zinc chloride solution and 20 parts of creosote by volume at approximately 70° Fahr.

[d] 3 per cent zinc chloride solution plus creosote. Treatment consisted of bath in hot creosote for 30 minutes at atmospheric pressure followed by pressure treatment with 3 per cent zinc chloride solution.

[e] Obtained from regular stock of C. M. St. P. & P. Ry.

[f] 4 per cent zinc chloride solution.

[g] 3 per cent zinc chloride solution.

[h] Steeping treatment in cold mercuric chloride solution. Absorption figures not available.

[1] Average life 8.7 years.

[2] Average life 9.2 years.

CONDITION OF EXPERIMENTAL TIES IN THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILWAY TEST TRACK NEAR HARTFORD, WIS., AFTER ABOUT 23¾ YEARS SERVICE

Ties set October 1911

Ties inspected June 1935

Preservative	Process	Tie plates	Average absorption	Ties in test	Good		Splitting		Decaying		Removed			
											Mainly for decay		For causes other than decay[a] and unknown causes[b]	
					No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent
			Lbs. per cu. ft.											
					RED OAK									
Creosote	Full cell	None	11.2	52	23	44.2	27	52.0	1	1.9	...	......	1	1.9
Creosote	Full cell	Flat	10.9	50	22	44.0	26	52.0	1	2.0			1	2.0
Creosote	Rueping	Flat	5.0	50	18	36.0	17	34.0	13	26.0	1	2.0	1	2.0
Creosote	Rueping	None	5.7	50	9	18.0	30	60.0	8	16.0	2	4.0	1	2.0
20% creo., 80% zinc chloride	Card	None	15.5[c]	50	5	10.0	12	24.0	29	58.0	1	2.0	3	6.0
20% creo., 80% zinc chloride	Card	Flat	15.2[c]	50	7	14.0	7	14.0	36	72.0	...	......	......	......
Semi-refined paraffin oil	Full cell	Flat	8.4	50	4	8.0	3	6.0	41	82.0	2	4.0	......	......
Semi-refined paraffin oil	Full cell	None	6.2	49	2	4.1	11	22.4	27	55.1	4	8.2	5	10.2
Zinc chloride-creosote	Two movement	Flat	14.7[d]	50	7	14.0	8	16.0	31	62.0	3	6.0	1	2.0
Zinc chloride-creosote	Two movement	None	16.0[d]	50	2	4.0	9	18.0	29	58.0	7	14.0	3	6.0
Zinc chloride	Burnett[e]	Flat	12.5[f]	157	......	......	......	......	18	11.5	100	63.7	39	24.8
Zinc chloride	Burnett[e]	Flat	12.5[f]	49	......	......	......	......	11	22.4	24	49.0	14	28.6
Zinc chloride	Burnett[e]	Ribbed	12.5[f]	53	......	......	......	......	13	24.5	22	41.5	18	34.0
Zinc chloride	Burnett	None	15.8[g]	50	......	......	......	......	34	68.0	13	26.0	3	6.0
Zinc chloride	Burnett	Flat	16.4[g]	50	......	......	......	......	39	78.0	6	12.0	5	10.0
Untreated[1]	......	None	......	50	......	......	......	......	......	......	50	100.0	......	......
Untreated[2]	......	Flat	......	50	......	......	......	......	......	......	50	100.0	......	......
					SPRUCE									
Mercuric chloride	Kyan	Flat	h	13	......	......	1	7.7	8	61.5	4	30.8	......	......
Mercuric chloride	Kyan	None	h	12	......	......	1	8.3	4	33.4	5	41.7	2	16.6

[a] Rail cutting, splitting, etc.

[b] Ties not available for examination after removal to determine the cause of removal.

[c] Emulsion of 80 parts of 3 per cent zinc chloride solution and 20 parts of creosote by volume at approximately 70° Fahr.

[d] 3 per cent zinc chloride solution plus creosote. Treatment consisted of bath in hot creosote for 30 minutes at atmospheric pressure followed by pressure treatment with 3 per cent zinc chloride solution.

[e] Obtained from regular stock of C. M. St. P. & P. Ry.

[f] 4 per cent zinc chloride solution.

[g] 3 per cent zinc chloride solution.

[h] Steeping treatment in cold mercuric chloride solution. Absorption figures not available.

[1] Average life 8.7 years.

[2] Average life 9.2 years.

Northern Pacific Railway Company

RECORD TEST TRACK No. 1–A

Location Milepost 89, near Rice, Minn., to Milepost 103½, near Gregory, Minn. In Eastward main track on St. Paul Division. Ties laid in Spring of 1917. Established as record test track January 10, 1922.

Ties 44,159 Hewed Minnesota Tamarack.

Treatment Brainerd Tie Treating Plant, December, 1916. Air Seasoned. Bored and Adzed for 90-lb. rail. Treated by Lowry Process. 6¾-lb. per cu. ft. with creosote coal-tar solution, 80 per cent creosote and 20 per cent refined coal tar.

Analysis of above mentioned preservatives:

Specific gravity at 38° C.	1.074
Water	.000

Distillation:

210°	1.1	per cent
235	10.7	
270	28.6	
315	15.2	
355	18.7	
Residue	25.6	Soft paste

Track Originally 90-lb. rail with N.P. standard angle bars and 7″ × 9″ tie plates. In 1923 about three and a half miles of washed gravel from Darling Pit was placed on the east end of this track. In 1928 four miles (M.P. 93½ to 97½) were relaid with 100-lb. rail and 7¾″ x×10¾″ tie plates.

Renewals No renewals up to 1928.
1928— 1 Tie account decay. Showed signs of having been partially decayed when treated.
1929—239 Ties account derailment.
1930— No renewals.
1931— 3 Ties account decay.
1932— No renewals.
1933— " "
1934— " "
1935—214 Decay at rail base caused by mechanical wear. No renewals under 100-lb. rail this year.

Total 457 Ties renewed—1.04 per cent after 18 years.
Average life of ties removed—14.8 years.
Date of last inspection—October 24th, 1935.

Northern Pacific Railway Company

HEMLOCK TEST TRACK

Designed by U.S. Forest Service as Project L–214

Location Between M.P. 120 and M.P. 121–2350. Westward Main Line, West End of Missoula Yard. 400 Ties East and 1,400 Ties West of Cemetery Crossing, Missoula, Mont., Rocky Mountain Division.

Ties 1,800 (Summary by species shown below) Treated at Paradise, Mont., and placed in track February, 1910. 1910 Dating Nail driven in each tie.

Treatment At Paradise Tie Treating Plant, February, 1910. Air-seasoned, not Bored, Adzed or Incised. Lowry Process. 6¾-lb. per cubic foot. Creosote Coal-Tar Solution. 80 per cent No. 1 Creosote and 20 per cent Refined Coal Tar.

TRACK Ties originally laid without Tie Plates. 7″ × 9″ Tie Plates applied within first two years. In 1926 track relaid with 100-lb. rail and 7¾″ × 10¾″ N.P. Plates. Ballast is ordinary pit-run gravel and drainage is not considered good.

SUMMARY BY SPECIES AND RECORD OF RENEWALS

Annual inspections and reports made since 1917 when on account of derailment the first tie was removed. Positive identification of ties by species made in 1928 in cooperation with U.S. Forest Products Laboratory proved as shown below. The 49 ties replaced previously had been reported as Western Hemlock.

Identification of 1910 Ties Remaining in 1928	*Ties Laid 1910*	*1917*	*24*	*26*	*28*	*29*	*32*	*33*	*34*	*35*	*Total Ties*	*Per Cent*	*Average Years Per Tie*
Western Hemlock ..	1072	1	1	4	43	26	49	28	43	29	224	21.00	21.13
Western Larch	436					8	9	8	18	9	52	11.93	22.90
Douglas Fir	166					6		4	1	5	16	9.61	22.19
True Fir	102					14		1	6	4	25	24.51	21.32
Spruce	18					5	3	1			9	50.00	20.44
White Pine	2			None									
Ponderosa Pine	3			None									
Aspen	1			None									
Totals	1800	1	1	4	43	59	61	42	68	47	326	18.11	21.76

Six ties removed prior to 1928 were broken by derailments. Others all removed account decay hastened by damage from past derailments and mechanical wear at rail base.

18.11 per cent renewals after 25 years. Average life of ties replaced, 21.76 years.

NORTHERN PACIFIC RAILWAY COMPANY

Test Track No. 8-B, Third Sub-Division, Rocky Mountain Division (Phileman Line Change) Mile Post 156 plus 5198 to Mile Post 157 plus 1259. Established in 1923.

TIES 120 Untreated White Oak grown in Minnesota and placed in track in July, 1923.

TRACK 19 ties per panel of track; Ballast—ordinary pit-run gravel; Rail—90-lb. laid in 1923, N.P. Standard angle bars, with heat-treated bolts with locknuts; N.P. standard tie plates 7½″ × 10¾″; 8 Henggi type rail anchors per panel of track.

RENEWALS

Years	*Ties*	*Per Cent*	*Average Years Life*	*Cause for Removal*
1931	22	18.3	8.0	Decay
1932	5	4.2	9.0	"
1933	21	17.5	10.0	"
1934	30	25.0	11.0	"
1935	42	35.0	12.0	"
Total	120	100.0	10.5	

Appendix C

(3) PILING USED FOR MARINE CONSTRUCTION

Wm. G. Atwood, Chairman, Sub-Committee; C. C. Cook, H. R. Condon, L. H. Harper, G. R. Hopkins, H. E. Horrocks, A. M. Knowles, F. D. Mattos, C. M. Taylor.

The Committee submits herewith report on the present condition of the long-time test pieces under its observation together with such other pertinent information as it has obtained during the year.

Tropical Timber

Angelique or Basra Locus *(Dicorynia paraensis Benth)*. Balboa, C.Z. Source Dutch Guiana. Size 8″ × 8″ × 24″; submerged September 13, 1923. A 6-in. section was cut (Fig. 1). The end exposed by the cut showed many teredo openings but dissection made it evident that all shipworms were confined close to the surface or leading from vacant pholad cavities. There were a large number of pholads present, many of them dead. The principal damage was caused by these pholads, otherwise the timber is very sound.

Manbarklak *(Lecythus ollaria L.* or *Eschwilera longipes Miers)*. Balboa, C.Z. Source Dutch Guiana. Size 8″ × 8″ × 24″; submerged September 13, 1923. Much encrusting growth, especially sponges. Both pholads were present and fairly abundant but the teredo were small, few in number and confined close to the surface. Limnoria damage light. The timber is very sound, except for the pholad damage.

Greenheart *(Nectanda rodice Schomb)*. Balboa, C.Z. Source Demarara. Size 8″ × 8″ × 24″; submerged September 13, 1923. Much encrusting growth including oysters. Many teredo and pholads, some of the former ½-in. in diameter. After 12 years immersion this test has been closed (Fig. 2).

Balboa, C.Z. Source Demarara. "Light Brown Heart". Size 8″ × 8″ × 31″; submerged July 18, 1932. Heavy encrusting growth especially sponges. Many teredo holes, some ½-in. in diameter. The Panama Canal report says: "In so far as our tests are concerned, this timber has already failed".

Balboa, C.Z. Source Demarara. "Dark Brown Heart". Size 8″ × 8″ × 31″; submerged July 18, 1932. Condition about the same as above. Report says: "This timber is also a failure, despite its dark brown heart".

Balboa, C.Z. Source Demarara. "Yellow Heart". Size 8″ × 8″ × 31″; submerged July 18, 1932. Some pholads and teredo "abundant".

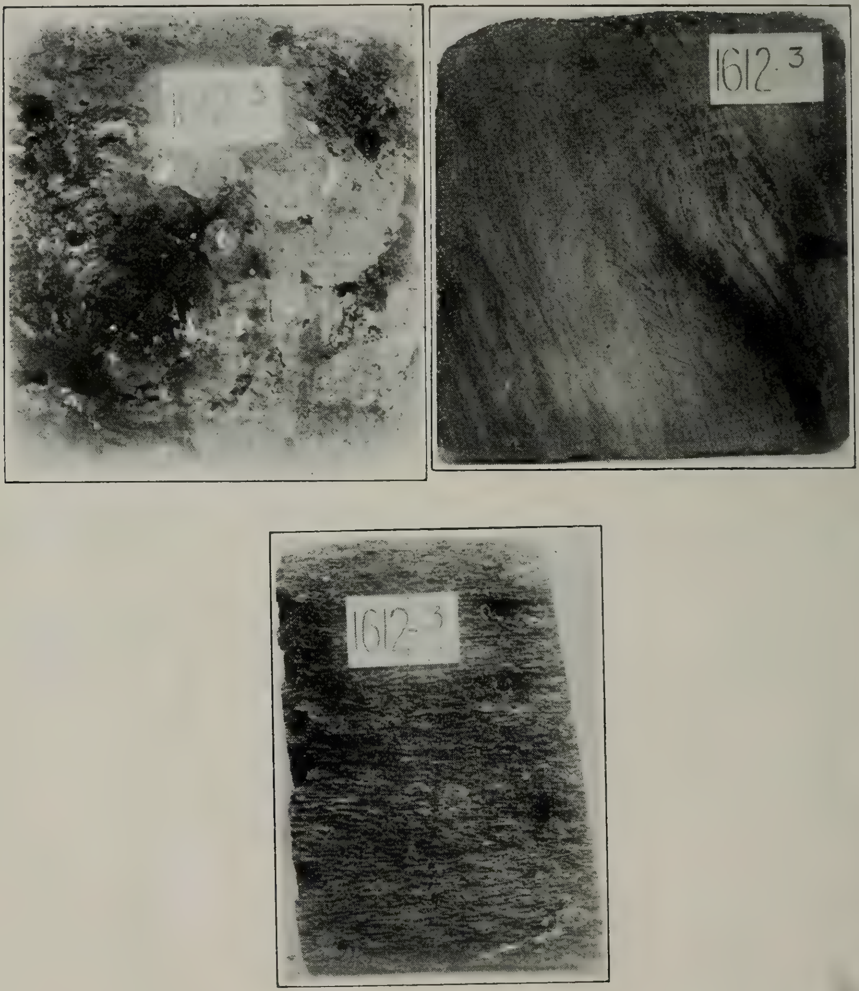


Fig. 1.—1612–3 Basra Locus or Angelique. Dicorynia paraensis Bentham. Appearance of end and of section 6 inches from the end; also view of one of the sides. 12 years' exposure.

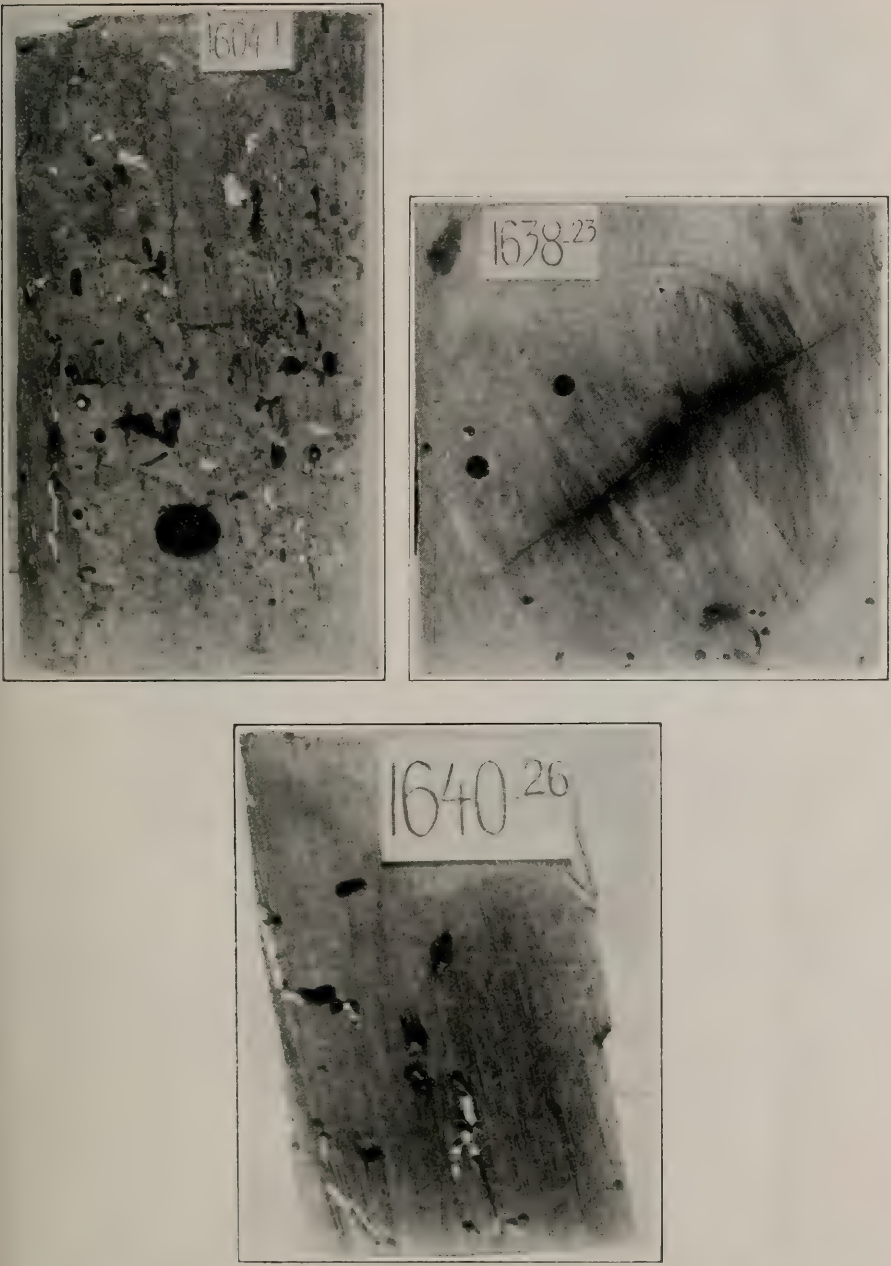


FIG. 2.—GREENHEART, *Nectandra rodice*. 1604–1 appearance of one side, 12 years' exposure. 1638–23, light brown heart, appearance of section 6 inches from end. Three years' exposure. 1640–26, yellow heart, appearance of split section 6-in. from end. Three years' exposure.

Balboa, C.Z. From Panama Canal Stock. Size 4″ × 8″ × 24″; submerged Sept. 26, 1931. Heavy encrusting growth especially sponges. Sides literally peppered with teredo openings. Badly riddled and had large teredo. Both pholads present. (Fig. 3).

TURPENTINE WOOD *(Syncarpia laurifolia).* Balboa, C.Z. Source New South Wales. Size 6″ × 6″ × 33″; submerged April 19, 1929. No change since last inspection. Attack only in their sapwood. Timber very sound.

Same size and date as above. A section was cut and shows only a few small teredo holes near the sides. The center is sound. A few pholads present.

Charleston, S.C. Submerged Sept. 12, 1929. Heavily attacked by both teredo and limnoria. Test closed.

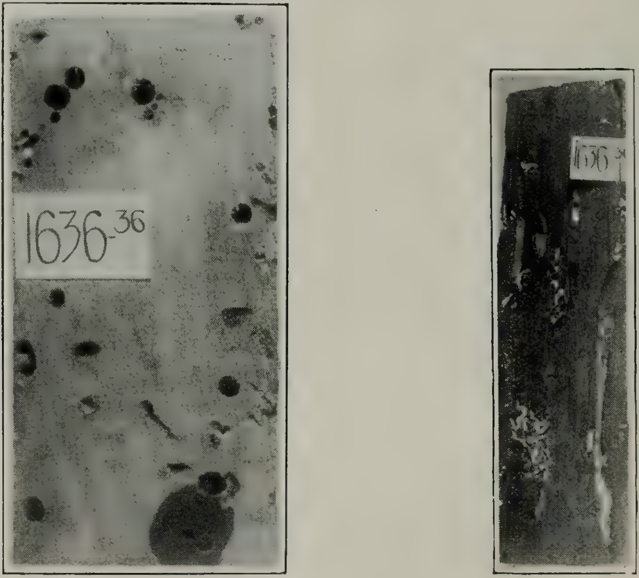


FIG. 3.—1636–36 GREENHEART *(Nectandra rodice).* Appearance of section six inches from end, and of the balance of the timber split in two. 4 years' exposure.

Oakland Pier, Oakland, Cal. Fifty piles purchased by the Southern Pacific as *Syncarpia laurifolia* and driven in the spring lines of the slips 1927–28. Prof. Record of Yale University stated that this timber was of some other species of Myrtaceae but the service record is interesting and the professor may have been mistaken in his report.

Inspection was made July 18, 1935 after about 7½ years service. A number of the piles have been broken but the condition of those remaining was found to be as follows:

Pile 11—No attack found.
15—Heavy Limnoria attack.
16—Moderate " "
17— " " "
18—Very light " "
19—No attack found.
21—Very light Limnoria attack.
22— " " " "
23—No attack found.
24—Heavy Limnoria attack.
25—No attack found.
26—Very light Limnoria attack.
27—Light " "

28—No attack found.
29— “ “ “
30—No attack on water side in 1935; in 1932 the wharf side of this pile showed a very slight Limnoria attack and two teredoes 3″ to 4″ long.
31—Very light Limnoria attack; 2 teredos found.
32—Heavy Limnoria attack; a few teredos found.
33—Moderate “ “ “ “ “ “
34—Light “ “
39—Pile is broken; very light Limnoria attack.
40—Heavy Limnoria attack.
41—Very light Limnoria attack.
42— “ “ “ “ 1 teredo found.
43—Moderate “ “
44— “ “ “
45— “ “ “
46— “ “ “
48— “ “ “
49— “ “ “
50— “ “ “

Pile No. 35 was broken and removed in February 1934; it was found to have sustained a heavy Limnoria attack in the sapwood but none on the heartwood. No teredos were found.

So far as has been determined from inspections to date the attack is entirely in the sapwood. The heartwood is penetrated by beetle holes, but there has been no evidence of Limnoria using these holes as a starting point for attack on the hard heartwood.

PANAMA CANAL

Through the courtesy of Col. Julian L. Schley, Governor of the Panama Canal Zone, we are able to present the following report on tests in addition to those quoted previously in this report.

"In connection with the annual inspection of timbers undergoing test for resistance against marine borers at Balboa, Canal Zone, please be advised that the 1935 inspection was performed by James Zetek on August 5th, and under date of August 17th he has submitted the following report with the attached photographs:

"My remarks in the 1934 report as to 'marine growth' and gribble, apply also this year. Sponges appeared to be the more dominant and abundant forms. Ascidians were not as plentiful as heretofore.

The two pholads which we have been encountering in nearly all of these timbers, are *Parapholas Acuminata* Sby, and *Martesia Intercalata* Cpr. The Martesia seems to fit in every way Carpenter's description. His species was never figured, and the type specimens are like ours, apparently juvenile, in that the anterior hiatus is not closed by calcareous extensions of the valves, as we expect to find in mature individuals. Many of the pholads this year were dead, due to silting.

"The dominant teredo was *Neobankia Zeteki* Bartsch. I did not try to save every shipworm in order to determine if other species were also present, but the many I did examine are the above species. In some of the more resistant timbers, the teredo is found only close to the surfaces, *and* about vacant pholad cavities. The latter situation drives it further into the timber. In such woods the teredos are all small in size.

"The following tests were closed at this time:

1604–1 Greenheart, Nectandra rodioe
1636–36 “ “ “
1709–16, C.W.S. c-17 (creosote plus 0.77 per cent diphenylaminochlorazine) (21.3 lbs. per cubic foot)

"Photographs of the following accompany the report:

1604–1 Greenheart (1)
1612–3 Basra Locus (Angelique) (3)
1640–26 Greenheart (1)

1636–36 Greenheart (2)
1638–23 Greenheart (1)
1621–25 Turpentine Wood (1)
1718–34 Almendra, copper cement paint.

"Greenheart, irrespective of the color of the heartwood, insofar as the teredo is concerned, behaves the same

(A)—UNTREATED TIMBERS

"ANOUKA, Conepia sp., from Dutch Guiana; No. 1609–2; 8″ × 8″ × 24″; submerged September 13, 1923. Gribble damage to surfaces about the same as last year. Much marine growth on all sides and end. Both pholads present in numbers. Teredos all small, apparently confined close to the surfaces. Except for the gribble and the pholads (the latter exceeding the teredo in damage done) the wood is very sound.

"FOENGO, Parinarium campestre Aubl., from Dutch Guiana; No. 1608–4; 8″ × 8″ × 24″; submerged September 13, 1923. Abundant marine growth on all sides and ends, especially sponges and oysters. Both pholads plentiful. Gribble damage about the same as last year. Teredos plentiful, but very small and close to surfaces. Timber otherwise is very sound.

"SPONSE HOEDOE, Licania macrophylla Bentham, from Dutch Guiana; No. 1610–5; 8″ × 8″ × 24″; submerged September 13, 1923. Sections were cut in 1932 and 1933, none this year. Gribble work about as last year. Much marine growth, especially sponges. Both pholads plentiful. Teredos appear to be few in number, small, confined close to the surfaces. Otherwise the timber is very sound.

"MALABAYABAS from the Philippine Islands, No. 1606–9; 12″ × 12″ × 13″; submerged September 13, 1923. A very heavy timber. Much marine growth, especially sponges and oysters. Gribble work light. Both pholads plentiful. Teredos all small, few in number, close to surfaces. Timber otherwise sound.

"KAJOL LARA, Metrosideros sp., from the Celebes, No. 1615–11; 6½″ × 6½″ × 30″; submerged October 26, 1925. Surfaces have more marine growth especially sponges, than heretofore. Both pholads plentiful. Teredo appears to be limited in number, small, and near to surfaces. Gribble work very light. Timber otherwise very sound.

"KAJOL MALAS, Parastemon urophyllum, from Sumatra, No. 1616–12; 6″ × 6″-× 30″; submerged October 26, 1925. More marine growth, especially sponges, than before. Both pholads present but few in number. Teredos few in number, small, close to the surfaces. Gribble very light, timber sound otherwise.

"KOLAKA, from the Celebes, No. 1637–13; 6″ × 6″ × 30″; submerged April 15, 1932. Much more marine growth, especially sponges, than heretofore. Teredos few, small, close to surfaces. Gribble practically nil. Timber sound.

"ALCORNOQUE, Dimorphandra mora B. & H., from Panama, all heartwood; No. 1617–14; 6″ × 6″ × 53″. Submerged November 22, 1927. Less marine growth. Both pholads present, but not plentiful. Gribble almost nil. Teredo apparently not plentiful. Timber in excellent shape.

"BRUSH BOX, from New South Wales, No. 1625–22; 6″ × 6″ × 24″; submerged April 19, 1929. No change noted from condition last year. Very good timber.

(B)—TREATED TIMBERS

"AMARILLO, Chlorophora tinctorea, from Panama, treated with AREA No. 1 coal tar creosote; No. 1630–30; 9½″ × 12½″ × 9 ft.; one end scarfed after treatment. General condition much as last year. Much marine growth, some mud. We cut an eight inch section from the end *Not* scarfed. Creosote penetration as seen in the cut end was extra good and deep. No TEREDOS found in the cut end, and none found when this section was split up into small pieces. While cutting this section exposes parts of the timber having less creosote, the section was warranted in that it gave information we could not get any other way. It will be of interest to note what will happen now that the end is better exposed to teredos. The timber was in perfect condition.

"PANAMA CANAL COPPER CEMENT PAINT TREATMENT. Creosoted fir, No. 1714–29, Panama Canal stock. Ends only coated with the paint, 3″ × 12″ × 30″. Much marine growth, especially sponges. We did not cut into it. It appears to be in very good shape.

"As above, except untreated Almendra, Panama Canal stock, No. 1718–34, size 6″ × 6″ × 30″. Much marine growth, especially sponges. An 8″ section was cut. The surfaces appear to be in good shape, but the cut face had four teredo holes, the largest ¼-inch in diameter. See photograph of a split section which shows many teredo holes. It is very doubtful if a paint of this sort can protect timber for any appreciable time.

"As above, except GREENHEART, No. 1719–35, untreated, Panama Canal stock, 6″ × 6″ × 30″. Much marine growth especially sponges. A six inch section was cut. The cut face had one teredo hole, otherwise very sound. Having cut this section, the test is no longer one of copper cement paint.

"The above three tests were installed April 20, 1933."

CHEMICAL WARFARE SERVICE SPECIMENS

SERIES No. 1

This series of test pieces were treated by the Chemical Warfare Service in their experimental cylinder at the Edgewood Arsenal. Treatment with the following preservatives:

No. 1: 1 per cent solution of ammonical copper carbonate.
No. 2: 1 per cent diphenylamine chlorarsene in creosote.
No. 3: 0.75 per cent dyphenalamine chlorarsene and 0.5 per cent phenyldichlorarsene in fuel oil.

Except at the following stations these test pieces have been abandoned because of heavy attack. All specimens were submerged during the summer of 1925.

No. 1. San Juan, P.R. Attacked by Limnoria and less heavily attacked by Teredo.
Coco Solo, C.Z. Limnoria attack increased. Teredo attack much heavier.
Oakland Pier, Cal. Light Limnoria attack on ends in 1934.
Port Costa, Cal. There was a slight attack by Limnoria in 1932 and 1933 but the inspection of Aug. 27/35 showed a heavier Limnoria and Bankia attack in several locations.

No. 2. San Juan, P.R. Light Limnoria attack on bottom.
Coco Solo, C.Z. Slight Limnoria attack in one spot, but wood is becoming spongy on the surface.
Oakland Pier, Cal. No attack.
Port Costa, Cal. Light Limnoria attack.
Puget Sound Navy Yard. No attack.

No. 3. Oakland Pier, Cal. Moderate Limnoria attack on end.
Port Costa, Cal. Heavy Limnoria attack all over.

At all these test stations the Limnoria and Teredo or Bankia attack on the untreated control pieces was heavy except on the San Francisco Bay pieces where the Bankia attack was light.

SERIES No. 2

Test specimens were treated at Edgewood Arsenal in 1931. The materials used were AREA No. 1 Creosote as controls and the same material to which had been added varying proportions of methylarsenious oxide, diphenylamine cherarsene, dinitrophenol and petroleum residium reinforced with the same chemicals.

These test pieces were distributed and placed by the U.S. Army at Ft. Tilden, N.Y., and Castle Pinckney, S. C.; U S. Navy Yard at Pensacola, Fla., Puget Sound Navy Yard; Pearl Harbor, H.I. Navy Yard and Cavite P.I. Naval Station; Bureau of Lighthouses at San Juan, P.R.; Panama Canal and Southern Pacific Company at Oakland and Port Costa, Cal.

The creosoted pieces show little or no attack except at Pearl Harbor and Cavite where some Martesia attack was recorded but there was no indication that the chemicals added to the creosote had had any effect so far.

The petroleum treated pieces were generally speaking heavily attacked except at Fort Tilden and in San Francisco Bay where a relatively light attack occurred.

TEST SPECIMENS IN SAN FRANCISCO BAY AREA

These specimens were treated with various creosotes and fractions of creosote and were placed in 1923.

The change in condition since the report of 1934 is very slight in most cases though untreated controls showed heavy limnoria and light Teredo and Bankia attack.

1935 REPORT ON TEST PILES

The following Tables 1-A to 1-D, give the 1935 condition of four sets of test piles driven in 1919 and 1920 at Seattle, Washington, Tiburon, on San Francisco Bay, San Pedro and San Diego. Each set originally consisted of seven piles, including the following:

3 old creosoted fir piles originally driven in 1890.
1 do. 1901.
2 new freshly creosoted fir piles originally driven in 1919–1920.
1 " untreated fir pile originally driven in 1919–1920.

The untreated piles were destroyed in three to four years, as shown in Table 1-D, leaving six piles in each set.

The set at San Diego was exposed for test by the Atchison, Topeka and Santa Fe Railway Company at their wharf No. 63, until the wharf was dismantled in 1925. After being repaired the piles were redriven by the Southern Pacific Company at Long Beach, California, and the test continued.

It has been customary to make an annual diver inspection of the test piles which the Northern Pacific installed under its dock No. 1 at Seattle, but as inspections of recent years have shown these piles entirely free from teredo and the diver inspection of November 24, 1933, was very thorough an inspection at low tide was made for this report.

There was practically no change found in the condition of either the 1890, 1901 or 1920 piles from that shown in last year's report.

NEW ENGLAND MARINE BORER ATTACK

The work described in the 1934 report has been continued under the same organization except that after the untimely death of F. C. Shepherd, he was succeeded as Chairman of the Committee by A. H. Morrill and several additional organizations have cooperated in the work. The information obtained is abstracted below:

MAINE

In previous investigations no marine borers have been found in any quantity east of Portland.

In 1934–35 test boards were maintained at Eastport, Calais, Machias, York, Machiasport, Thomaston, Penobscot River, Taunton River, Mt. Desert, Bangor, Searsport, Wiscasset, Rockland and Bath. No teredo were found in blocks and Limnoria in sufficient numbers to indicate danger only at Eastport, Bath, Wiscasset and Rockland, they being in the largest numbers at Rockland.

Timber taken from the waters of Boothbay Harbor showed a heavy attack of Teredo navalis and they were also found at Searsport.

Lobster car timber from Brant Rock, Green Harbor River was very heavily attacked by Teredo navalis and probably two other species of teredo.

A coal wharf at Belfast was very seriously damaged by Teredo.

PORTLAND HARBOR

The 1922–24 investigation showed Limnoria damage only on the Grand Trunk wharf with no evidence of Teredo. In 1934 Limnoria were found in large numbers on the property of the Portland Terminal Company.

In 1935 a fairly heavy attack was found on Wharf No. 4 concentrated within about 8 ft. of the bottom.

On Wharf No. 3 the Limnoria attack in 1935 seems to be of less intensity than in 1934 and this is also true of Wharf No. 1.

The heavy attack seems to be within a few feet of the bottom and few Limnoria were found far above this point.

65 piles in Wharf No. 1 were examined and it was found that about 20 were not attacked or showed only a light attack while the remainder showed a heavy attack. 28 piles contained from 1 to 6 Teredo. These piles were driven in 1931.

Two pile sections from the Portland Terminal Company bridge had been cut off by Limnoria and also contained 2 Teredo.

NEW HAMPSHIRE

Portsmouth.—Test boards on the B.&M. bridge in 1922–24 showed a few scattered Limnoria. In 1934 the attack on blocks was heavy for a short time but in 1935 it was very slight. Several pile sections examined showed Limnoria attack to a depth of 2-in. to 3-in. and some of the piles contained live Teredo but no considerable number.

The blocks taken from the Hampton Toll Bridge showed very heavy encrusting growths of a kind which indicated the possibility of Teredo attack but no Teredo and only a few Limnoria were found.

DOVER.—Teredo were found in submerged timber.

MASSACHUSETTS—NORTH OF BOSTON

Newburyport.—1922–24 blocks showed practically no life, while blocks from spring of 1934 to fall of 1935 show heavy incrustation, but no borers.

BEVERLY.—In 1922–24 a very slight encrusting growth while in 1934–35 the encrustation was heavy and a fairly heavy Limnoria attack was found close to the mud line.

Revere.—There was little change from 1922–24 to 1934–35 except a great increase in encrusting organisms.

Boston Harbor.—A considerable number of additional test boards have been placed during the last year and many examinations have been made by divers and of piles and timber removed from structures.

Boston Harbor.—1922–24 showed evidence of the presence of Limnoria but in significant numbers in only one or two locations. The 1934–35 investigations have proven the presence of Limnoria, generally in large enough numbers to be very destructive, in practically all parts of the harbor. Teredo are also found in many locations even so far as the Mystic and Charles Rivers.

Chelura, which is a species of crustacean previously found only in isolated specimens in the United States has appeared in enormous numbers at the Army Base and in numerous other piers. They seem to be driving out the Limnoria.

Very little is known regarding this species of borer, but it is reported to be even more destructive than Limnoria in foreign harbors where it exists. Its appearance in Boston and its rapid spread to other New England harbors is very disturbing.

The Army Base piers are to be enclosed in steel sheet piling and filled at a cost in excess of $1,000,000. This seems to be the only chance for saving these important structures, because pile replacement is impossible on account of the type of construction.

It is understood that a decision as to what is to be done with the Commonwealth Piers has not been reached.

A large number of contracts have been let for the replacement of untreated piles by creosoted piles, but unfortunately there have also been a considerable number of untreated piles used.

From the evidence obtained in 1934 and 1935 it appears that there is, with the possible exception of small areas, where pollution is so heavy as to have exhausted the oxygen in the water, no part of Boston harbor where structures on untreated piles are not in imminent danger. The attack in general by Limnoria and Teredo seems heavier and more widespread than a year ago and the Chelura attack is new and heavy.

MASSACHUSETTS—SOUTH OF BOSTON.—Test boards were maintained at Neponset, Quincy, Scituate, Marshfield, Truro, Bourne, Sandwich, Chatham, Hyannis, Marion, Provincetown, Woods Hole, New Bedford, Vineyard Haven, Nantucket and Fall River.

The attack at Neponset and Quincy was entirely by Limnoria rather light in the former and somewhat heavier in the latter. Teredo were found in submerged timber at Quincy.

At Scituate, Marshfield, Truro, Bourne, Sandwich and Chatham, the Teredo attack was very heavy in 1934, but much lighter in 1935, none at all having appeared at Scituate. Limnoria attack was fairly heavy both years.

At Hyannis, Woods Hole, Marion, Vineyard Haven, Nantucket, New Bedford and Provincetown, the Limnoria and Teredo attack was very heavy both years. Chelura appeared in 1935 at all points except Vineyard Haven.

Fall River had an exceedingly heavy attack by both Teredo and Limnoria in 1934 and only a few Limnoria in 1935, but Chelura were active.

RHODE ISLAND

Tiverton.—The Teredo attack was extremely heavy in 1934 but was rather light in 1935.

Newport.—A very heavy Teredo and Limnoria attack in 1934 and one Chelura found. In 1935 the Teredo attack was much lighter but that of Limnoria and Chelura was fairly heavy.

Barrington Bridge, Hampton Meadows.—There was a heavy attack of Teredo and Limnoria in 1934, but no specimens of either species had been found up to Sept. 2, 1935.

CONNECTICUT

Mystic River.—A relatively small number of Limnoria appeared on most of the blocks.

Saybrook.—A few Teredo were found in most of the 1934 blocks but none appeared in 1935.

Allyn's Point.—No borers either year.

Shaws Cove—New London.—A fairly heavy Limnoria attack helped by a few Chelura in 1934 and about the same condition in 1935 except that a few Teredo were found.

Niantic.—There was a heavy Teredo and a fairly heavy Limnoria attack in 1934 but neither animal has been found in 1935. Piling examined showed a heavy Teredo and Limnoria attack.

Guilford.—There was a fairly heavy Teredo attack in 1934 but none in 1935.

Belle Dock, New Haven.—Only a few Limnoria appeared.

Housatonic Railroad, Devon and at Bridgeport.—No borers and very little marine life.

Norwalk.—A few Teredo were found in 1934 and none in 1935.

NEW YORK HARBOR

Test boards were placed and blocks or boards examined for the New York, New Haven & Hartford Railroad at Baychester River and Float Bridge No. 2 Oak Point; for the Department of Plants and Structures and the Dock Department of the City of New York, at College Point, Willets Point, the Astoria Ferry Terminal, St. George Terminal, Staten Island, Whitehall Terminal, Penn. Railroad Terminal Bayonne, Ft. Hamilton, Barren Island, Mill Basin, Sheepshead Bay, Nortons Point, Coney Island and for the Central Railroad of New Jersey on their Newark Bay Drawbridge and the Erie and Delaware, Lackawanna & Western Railroad on their bridges over the Hackensack and Passaic Rivers.

The findings were very similar, except in Newark Bay and tributaries to those of the National Research Council in 1922–24. No borers in important quantities were found in the East River, Hudson River or upper Bay, though the encrustation was heavy in most locations. In the Lower Bay, Jamaica Bay and Rockaway Inlet, borers were present. There was a decided change in conditions in Newark Bay and the Hackensack and Passaic Rivers where no marine life was found in 1922–24 and a considerable amount of it in 1935. No borers were found but the water conditions are shown to be such as will permit them to live.

CANADA

An extremely heavy attack by both Limnoria and Teredo was reported and inspection by Mr. Clapp confirmed it in Newfoundland. This heavy attack is also reported to extend well up the Gulf of St. Lawrence.

BIOLOGICAL WORK

W. F. Clapp of Duxbury, Mass., and the Mass. Institute of Technology, continued his study of encrusting organisms associated with the borers and made progress. He also carried on studies as to the effect of temperatures, dissolved oxygen, hydrogen ion, turbidity and several other ecological factors.

It seems to be proven that no one of these factors controls the activity of the borers but that a favorable combination of several of them is necessary for borer attack.

SUMMARY

Panama Canal tests have now been carried on for 13 years with the result that Angelique, Manbarklak, Anoura, Foengo and Sponse Hoedoe from Dutch Guiana and Malabayabas from the Phillipines have all shown great resistance to attack. None of them have received more than surface injury in a location where untreated pine or fir would be practically destroyed in a year.

Several other tropical timbers show favorable indications but have not been under test so long.

Turpentine Wood from Australia has a good record at Panama and the Southern Pacific piles show a favorable result after a shorter period.

Greenheart has shown some resistance at Panama but its record is not such that, in that location at least, it should be used for important construction.

Of the first series of Chemical Warfare tests only one piece treated with fuel oil and arsenicals survives after 10 years and this treatment may be said to have failed.

The copper carbonate treatment has shown more resistance but it too cannot be considered a satisfactory treatment for permanent work.

The creosote reinforced with arsenicals is still good but this resistance may be largely because of the creosote itself.

The three treatments with petroleum and arsenicals of the second Chemical Warfare Series all show such heavy attack after four years that they may be considered to have failed.

Because of slight attack so far after 13 years, no conclusions can yet be drawn as to the relative value of the different creosotes in the Southern Pacific test.

The "Long Wharf" creosoted piles are not seriously attacked after 34 and 45 years service respectively.

The New England marine borer attack seems to be extending to the north and east of Boston but to be decreasing to the south and west except in a few harbors. The extremely heavy attack in Boston continues and has been found to be still more destructive than was thought last year because of a wider distribution of teredo and the appearance of Chelura.

Apparently practically all New England harbors should be considered subject to attack at times and consequently structures should be protected. The heavy destruction in 1935 is occurring in Boston, New Bedford, Woods Hole, around Buzzards Bay and at Martha's Vineyard, Newport and Nantucket.

There are no indications of a change in conditions in New York Harbor except in Newark Bay.

The appearance of a new borer, Chelura, in New England waters is very disturbing.

Conclusions

It is recommended that this report be accepted as information and the subject continued.

Appendix D

(5) DESTRUCTION BY TERMITES AND POSSIBLE WAYS OF PREVENTION

Dr. Hermann von Schrenk, Chairman, Sub-Committee; Wm. G. Atwood, C. C. Cook, E. A. Craft, F. D. Mattos, W. A. Summerhays, C. M. Taylor.

The Sub-Committee on Termites this year can make only a progress report because nothing which has not been referred to in previous reports has developed during the past year.

Termites are still very active. The Committee has had numerous advices from railroad engineers all over the country requesting information, all of which has been given.

The chief point of inquiry always deals with what shall we do with a building which is attacked by termites. In its report published in the 1935 Proceedings of the AREA pages 511 to 515 inclusive, suggestions for procedure were made. These naturally had to be very general because practically every case differs. It may be of interest to repeat some of the suggestions for preventive procedure with certain slight additions. The following should be noted:

All termite attacks except on the Pacific Coast and some parts of Arizona, New Mexico and Southern Florida, are due to the soil inhabiting form. The workers which do the destruction consequently must enter a building through the ground. They either get in through holes or cracks in the foundation wall and travel up the interior of the foundation wall to the overlying stringers or posts and thence to the rest of the building, or, they enter through pieces of wood either in the basement such as posts holding coal bin partitions, cellar stairs, etc. or through wood on the outside of the building. Or, they build tunnels from the earthen floor in the cellar or basement. These tunnels either run up the walls or along sewer or water pipes or they may even be vertical towers which reach the woodwork of the upper floor. One of the commonest forms of entrance into a building is found when two concrete slabs touch or where the concrete slab touches the walls of the building. As the concrete ages, it contracts slightly and leaves cracks either between two adjacent slabs of concrete or between the slab of concrete and the walls.

The workers travel from the inside of a building in which they are working to the outside ground and they do this continuously probably largely for the purpose of getting water supply. One can tell when termites are in a building either by noting the flying forms which occur in early Spring and sometimes the latter part of Summer, or by noting the destruction of wooden parts in wooden window frames, posts, door frames, etc.

The first thing to do after termites have been noticed is to explore the building in the region where most of the destruction is noted. This exploration should of course be carried out in the basement or the cellar. If there is a ceiling in the cellar, it should be torn off. One should then investigate the walls and endeavor to ascertain where the termites are coming into the building. When this point has been discovered the walls should be reconstructed, using a top dressing of very rich cement and of course putting termite shields as described in an early report, on top of the foundation wall. If they are coming in through a wooden post, cut off the post, remove all wood which is in the ground and put in a concrete pier on which the post can rest. If termites are coming up in the upstairs wall, investigate all joints between concrete slabs. If they are found coming in between slabs, chisel a trench between the two slabs and fill with a fairly soft coal tar pitch. If it is impossible to detect the exact point of entrance, a good safeguard is to expose the outside surface of the foundation wall clear to the bottom. After allowing the stone to dry, brush with a wire brush. Put on a coat of rich cement and after this is dry apply several coats of coal tar and tar-saturated felt.

While the above hints are necessarily very general, if one keeps in mind the fact that termites come from the soil into a building and that they can get in through woodwork in contact with the soil, that they enter through cracks in concrete slabs and that coal tar compounds, both creosote and coal tar pitch are repellents of great permanence, it will usually be possible to develop effective reconstruction methods.

The Committee considers it of equal importance to again emphasize the fact that proper design of a building in the process of construction is even more important than safe-guarding an old building. This means, have the foundation built of cement mortar. The foundation should extend for a considerable distance above the ground level if possible. Irrespective of what material the foundation wall is built, cover the top of the foundation wall with a coat of rich cement mortar and, on top of this put termite shields. Have no wood, except creosoted wood, in contact with the ground. Protect cellar window openings, door frames, etc., with rich cement mortar before the frame is inserted. Protect all water and sewer pipes where they come into a building with termite shields. For the first floor construction, use either creosoted lumber or use zinc treated lumber.

The Committee takes pleasure in presenting the following review of a book entitled, "OUR ENEMY THE TERMITE," by Dr. Thomas E. Snyder, Senior Entomologist of the United States Bureau of Entomology. This volume is published by the Comstock Publishing Company of Ithaca, New York, and sells for three dollars ($3.00). It consists of two hundred (200) pages; fifty-one (51) text figures and seven (7) plates. Your Committee has had an opportunity of reading the book, both in manuscript and in page proof and believes that every railroad engineer in the United States should have this book or have one where he can refer to it. It is estimated that termites cause $40,000,000 damage in the United States annually. Here is a book which tells how to build termite-proof structures and how to save structures infested by termites.

For twenty-six years Dr. Snyder has studied the termite and this book is the fruit of his research. It treats the termite from both the economic and entomological point of view for, as the author shows, it is impossible to prescribe methods of control until the type of termite involved and its life habits are understood.

The first six chapters discuss the place of termites among insects; the different species of termites; their life history and the caste system; their physiology and behavior, individual and social; their food; and the guests which sometimes dwell in the termite colony. Although completely authoritative and rigorously scientific, the book is so simply written that the layman can understand it without difficulty.

The four remaining chapters discuss the damage that termites do and methods of control. This section is especially suited to the needs of the city planner, the architect, the contractor, the home-owner and all who own or use any sort of wooden structures or supports. Here practical suggestions are made for building termite-proof houses and for saving structures already infested. The various methods of control now on the market are discussed and the fraudulent exposed. At the same time the question of termite menace is sanely treated and the unfounded fears which have arisen from ignorance on the part of the public are dispelled.

The appendix contains recommended provisions for city building codes, for insuring protection against termites and decay, a model tally sheet or form on which a building inspector can record the pertinent facts about termite damage and specifications for an agreement between the house-owner and a contractor undertaking to remedy termite damage to buildings.

The author's long experience makes both the scientific and the practical parts of the book completely reliable. The numerous illustrations heighten the value of the work.

The above information is offered as a progress report.

Appendix E

(6) EFFECT ON PRESERVATIVE IN TREATED TIES IN TRACK DUE TO BLOWING OFF LOCOMOTIVES ON LINE OF ROAD

C. S. Burt, Chairman, Sub-Committee; Z. M. Briggs, G. B. Campbell, H. R. Duncan, W. R. Goodwin, L. B. Holt, R. S. Hubley, R. P. Hughes, A. J. Loom, L. J. Reiser, T. H. Strate.

For some years, repeated questions have been asked by maintenance officers as to whether the blow-off of locomotives had any effect on creosoted ties. It has been generally observed that whenever treated water is used that for considerable stretches the ties in the sections where the blow-off was carried out looked very much bleached. In order to ascertain whether there was any loss of creosote, a number of determinations were made on Nickel Plate and Chesapeake and Ohio ties. These ties are described as follows:

NICKEL PLATE TEST

A creosoted oak tie was laid in 1925 and was removed from track in Perry, Ohio. This tie was selected because it was particularly bleached. On arrival at the laboratory, the tie was sawed in the following manner.

A section three inches thick was sawed from each end. These two pieces were discarded. A section 22 inches long was then sawed from each end. These two sections will hereinafter be called the "end sections". Next, 7½ inches were sawed from each end of the remaining piece. These two pieces were discarded. The remaining piece, 44 inches long, consists of the center section of the tie and was retained for examination. This, hereinafter, will be called the "center section". We then handled as follows:

The outer ¼-inch of the top surface from each piece was carefully removed. The outer quarter of an inch of the bottom of each piece was then similarly removed. The second ¼ inch from the top as well as from the bottom were then taken off. All of the samples from the two end sections were combined. There were then on hand, the outer ¼-inch, the second ¼-inch from the top and bottom of both the end sections and the center section. The creosote contained in these respective layers was then extracted in the usual manner. After extraction, the following figures were developed:

- (a) The specific gravity.
- (b) The percent of creosote found in wood based on the weight of dry wood.
- (c) Using the figure 40-lb. per cu. ft. for the average red oak, the pounds per cu. ft. for creosote were determined.

The idea was to find out whether any marked changes were evident in the character of the oil when comparing the extracted oil from the center of the tie, that is, the region subject to the blowoff and the oil from the ends of the tie, and also whether any differences were to be found between the oil in the top of the tie subject to blowoff and the oil in the bottom of the tie which naturally had not been subject to blowoff. It can be assumed that the blowoff might cause changes in the quantity of creosote as well as its character, because of the direct heat application, both of the water and steam falling on the ties during the blowoff period as well as subsequent thereto. These changes might be pictured as a loss in the quantity of oil due to volatilization of the lower boiling compounds of the creosote. If this had occurred, it would naturally have manifested itself both in the change in specific gravity and in lesser amount of oil in pounds per cubic foot. The results of this examination are given in the following table:

Sample Number	*Location in Tie of Wood Extracted*	*Sp. Grav. of Extracted Oil*	*Lb. per Cu. Ft. of Creosote Extracted*
241–A	Center of top—outside ¼-inch	1.114	2.10
241–B	Center of top—second ¼-inch	1.107	1.43
241–C	End of top—outside ¼-inch	1.122	2.28
241–D	End of top—second ¼-inch	1.103	1.61
241–E	Center of bottom—outside ¼-inch	1.119	2.79
241–F	Center of bottom—second ¼-inch	1.097	2.00
241–G	End of bottom—outside ¼-inch	1.110	3.06
241–H	End of bottom—second ¼-inch	1.091	2.31

A study of these figures includes the following:

The specific gravity of the creosote in the outer one-quarter inch of the center section is not markedly higher, in fact it is a little lower than the oil in the outer one-quarter inch of the ends. There is a smaller quantity of creosote in terms of pounds per cubic foot in the center section than there is in the ends. The specific gravity of the second one-quarter inch is a little higher in the center section but not markedly so and there is a lessened amount of oil per cubic foot in the center section for the second one-quarter inch. All this refers to the top layer. Looking at the second one-quarter inch at the bottom of the ends and center again, the specific gravity of the oil extracted is higher in the center section than in the ends. This of course could not possibly be ascribed to the blowoff. The quantity of oil per cubic foot is higher in the ends than in the center. The same relation holds true from the second quarter inch from the bottom.

Studying these results, it would be natural to expect more pounds per cubic foot in the ends than in the center because all oil penetrates into the ties through the ends and more stays there than in the center. The surprising thing about the matter is that the specific gravity of the oil in the upper one-quarter inch is lower than the specific gravity of the oil in the one-quarter in the bottom of the center section. It should be the other way round, because during the period (not considering the blow-off at all) the specific gravity of the oil will invariably increase due to the evaporation of the lower boiling compounds.

Taking these factors together, the examination of this tie does not seem to indicate any very serious change due to blow-off.

CHESAPEAKE AND OHIO TEST

A similar test was carried out on the Chesapeake and Ohio. Several red oak ties, creosoted in 1918, were removed from track at mile-post No. 469, near Scary, West Virginia. Of these ties, the one that looked most bleached was taken for analysis. This tie came from the east-bound track on a descending grade where engine crews blow down the locomotives on practically every train that passes. In this case, the tie was cut across the middle leaving half the tie. This half was cut into two pieces, an end piece 24 inches long and the remainder 48½ inches long. The outer quarter of an inch and the second quarter of an inch were shaved from the top as well as the bottom of these two pieces in exactly the same manner as was done for the Nickel Plate tie as above described. The oil was extracted and the same factors were determined as for the Nickel Plate tie. The results of the findings of this extraction are given in the following table.

Sample Number	*Location in Tie of Wood Extracted*	*Sp. Grav. of Extracted Oil*	*Lb. per Cu. Ft. of Creosote Extracted*
242–A	Center of top—outside ¼-inch	1.147	2.06
242–B	Center of top—second ¼-inch	1.123	1.43
242–C	End of top—outside ¼-inch	1.135	2.50
242–D	End of top—second ¼-inch	1.127	1.95
242–E	Center of bottom—outside ¼-inch	1.150	4.87
242–F	Center of bottom—second ¼-inch	1.120	4.32
242–G	End of bottom—outside ¼-inch	1.134	4.11
242–H	End of bottom—second ¼-inch	1.118	2.85

An examination of these figures indicates the following:

The specific gravity of the oil is slightly higher in the outside quarter of an inch of the center piece than the outer quarter inch from the end. This difference is not material, nor are the pounds per cubic foot materially lower in the top quarter inch of the center than in the top quarter inch of the end piece. The difference between both the specific gravity and the pounds per cubic foot of the top and bottom layers of the center and of the end may be accounted for by the fact that after ties have been in track for a certain period of time, the light oils are likely to evaporate from the top surface and the oil remaining in the wood in the top of the tie will always be correspondingly somewhat heavier than the oil extracted from the bottom of the tie because the latter is not exposed to the atmosphere and consequently there is less evaporation. As the low boiling compounds evaporate from the top layers, the preponderance of the heavier bodies would naturally make the specific gravity of the remaining oil heavier. Then too, one must take into account that the ends of the tie will usually absorb more creosote than the middle. If the blow-off therefore had caused any material evaporation of the creosote, the difference between the end and middle top quartr-inch should certainly have been greater than was actually found.

In order to obtain some information as to the temperatures which were involved during the period of blow-off, arrangements were made to carry out a series of temperature observations. A maximum registering thermometer and a laboratory thermometer were laid in the center of the track on a tie immediately before the passage of the train. In the following the findings of four tests which were made are given.

Russell, Kentucky, June 1st, 11:35 a.m.

Air temperature 90 degrees Fahr. Weather, clear. Light engine 3038, boiler pressure 250 lb. passed over thermometer at a rate of about four miles per hour with blow-off cocks open, steam and water from muffler striking ties for approximately 15 seconds. Following temperature readings were taken on tie:

Before blow-off	109 deg. Fahr.
Maximum registering thermometer	169 deg. Fahr.
Immediately after engine passed over tie	118 deg. Fahr.
After 1½ minutes	117 deg. Fahr.
" 3 "	110 deg. Fahr.
" 3½ "	106 deg. Fahr.
" 4 "	104 deg. Fahr.
" 5 "	101 deg. Fahr. Minimum

Russell, Kentucky, June 1st, 1:15 p.m.

Air temperature 90 degrees Fahr. Weather, cloudy. Temperature readings taken before and after engine 3037, boiler pressure 260 lb., with full tonnage train of 155 loads of coal, had passed over thermometers at rate of about ten miles per hour with both blow-off cocks open, steam and water from blow-off striking ties for approximately 1½ seconds. Following temperature readings were taken on tie.

Before blow-off	99 deg. Fahr.
Maximum registering thermometer	149.5 deg. Fahr.
After train had passed	88 deg. Fahr.
1½ minutes later	87 deg. Fahr.
2 " "	86 deg. Fahr. Minimum

Stevens, Kentucky, June 2nd, 11:45 a.m.

Air temperature 84 degrees Fahr. Weather, clear. Light engine 2306, boiler pressure 180-lb. ran over thermometers with both blow-off cocks open, water and steam from muffler striking ties for approximately 12 seconds. Following temperature readings were taken on tie:

Before blow-off	104 deg. Fahr.
Maximum registering thermometer	168 deg. Fahr.
After 15 seconds after blow-off	114 deg. Fahr.
" 1 minute " "	110 deg. Fahr.
" 2 minutes " "	108 deg. Fahr.
" 3 " " "	104 deg. Fahr.
" 4 " " "	100 deg. Fahr.
" 5 " " "	98 deg. Fahr.
" 7 " " "	95 deg. Fahr.
" 9 " " "	94 deg. Fahr. Minimum

While on this inspection, another temperature test was taken. Arrangements were made for Mikado Engine No. 2341, with local freight, to blow-off while passing mile post 469. This engine with twenty cars passed at a speed of about 40 miles an hour with blow-off cocks open and temperature was not sufficiently high to raise the recording thermometer to minimum registration of 100 degrees. The helper pusher engine, Mallet type No. 1391, was then brought up on the hill by the Road Foreman and passed over the thermometers with blow-off cocks open at a speed of about eight miles per hour. The air temperature was 80 degrees Fahr. and the weather was partly cloudly but with little wind. The following are the temperature readings taken on ties:

9:16 A. M.	before blow-off	82 deg. Fahr.
9:21 "	Maximum recording Thermo.	146 deg. Fahr.
9:22 "	Temperature on tie	98 deg. Fahr.
9:25 "	" " "	96 deg. Fahr.
9:27 "	" " "	89 deg. Fahr.
9:30 "	" " "	84 deg. Fahr.
9:31 "	" " "	82 deg. Fahr.
9:32 "	" " "	79 deg. Fahr.
9:33 "	" " "	77 deg. Fahr.
9:34 "	" " "	76 deg. Fahr.
9:35 "	" " "	75 deg. Fahr. Minimum

It will be noted that the maximum temperature reached in any of these tests, was 168 degrees Fahr. It will also be noted that this temperature is maintained for less than a minute, because immediately after the passage of the train, the temperature dropped very rapidly. Attention is called also to the fact that after several minutes, the temperature on the surface of the tie dropped below that observed before the blow-off. This happened in all four tests and may possibly be due to the evaporation of the water on the tie.

Considering both the extractions and these temperatures together it would appear that the temperatures indicated on the tie during the period of blow-off are so low that there is every probability that the oil loss would be small if any. This is particularly true when one remembers that at the period of maximum temperature, the surface of the tie was soaked with hot water which would have a retarding effect on evaporation. The results obtained from the extraction of the oil certainly warrant the statement that there is no evidence whatsoever of any changes, either as to the quantity or the chemical composition of the oil as found in the top center of the ties subject to blow-off. That is, in the region most subject to blow-off when compared with oil found in the ends of the ties outside the rail, and particularly when compared with the oil found in the bottom of the ties never subject to blow-off.

All of this can be summed up in the general statement that blow-off as now practiced on the Nickel Plate and Chesapeake and Ohio Railroads does not cause any loss of creosote from creosoted ties.

The above-described tests were carried out by Dr. Hermann von Schrenk, Consulting Timber Engineer of the Chesapeake and Ohio-Nickel Plate Railroads, and R. C. Bardwell, Superintendent of Water Supply of the Chesapeake & Ohio Railway. Dr. von Schrenk outlined the tests, and all the investigations dealing with extraction and analyzing of creosote were made in his laboratory. Mr. Bardwell supervised the tests on the track. The Committee takes this opportunity to express their appreciation for this interesting report.

It is the opinion of the Committee that results of the experiments described above quite possibly reflect the ultimate answer to this question, yet on the other hand we feel that additional data developed from further actual field tests are required before drawing definite conclusions. Accordingly such further experiments are now under way on several different railroads and results of these will be published from time to time as developments occur.

Conclusions

It is recommended that this report be accepted as information and the subject continued.

REPORT OF COMMITTEE XXI—ECONOMICS OF RAILWAY OPERATION

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R. E. Van Atta,
C. C. Williams,
S. L. Wonson,
John Worley,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual (Appendix A).

(2) Methods for Obtaining a More Intensive Use of Existing Facilities, with Particular Reference to Securing Increased Carrying Capacity. Progress.

(3) Methods or Formulae for the Solution of Special Problems Relating to More Economical and Efficient Railway Operation. Progress.

(4) Analyses to Determine when a Railway or Branch Line Should be Retired. Progress.

(5) Methods for Determining Most Economical Train Length, Considering all Factors Entering into Transportation Costs, collaborating with Operating Division. Progress.

(6) Effect of Volume of Traffic on Railway Operating Expenses, collaborating with Committee XXII—Economics of Railway Labor (Appendix B).

(7) Operation with Reduced Number of Main Tracks (Appendix C).

(8) Train Resistance as Affected by Weights of Rail, collaborating with Committee IV—Rail. Progress.

(9) The Economic Limits of the Movement by the Railway of Freight from Shipper to Receiver—by Rail, by Highway, or by a Combination of Both, collaborating with Committees IX—Highways, XIV—Yards and Terminals, and the Motor Transport Division. Progress.

With regard to assignments on which progress only is reported, your Chairman wishes to advise that much valuable data has been accumulated and work of considerable importance has been accomplished, which, it is hoped, will eventually be put in shape for the benefit of this Association.

The Committee on Economics of Railway Operation,
J. E. Teal, *Chairman.*

Bulletin 383, January, 1936.

Appendix A

(1) REVISION OF MANUAL

J. M. Farrin, Chairman, Sub-Committee; V. T. Boughton, S. W. Fairweather, C. H. R. Howe, M. F. Mannion, J. A. Parant, J. F. Pringle, L. S. Rose, B. J. Schwendt, J. E. Teal, R. E. Van Atta.

Your Committee presents the following report covering this subject:

(1) A Formula or Method of Calculating the Cost of Moving Freight Traffic. Delete from Manual. Now on page 1403.

(2) Feasibility and Economy of Through Routing of Solid Trains and its Effect upon the Capacity of Terminals. No change. Page 1421.

(3) Operation of Trains against the Current of Traffic on Multiple Track. No change. Page 1421.

(4) Method for the Determination of Proper Allowances for Maintenance of Way Expense due to Increased Use and Increased Investment. The attached, designated as A–1, to replace present subject-matter on page 1421.

(5) The Cost of Stopping and Starting Trains. The attached, designated as A–2, to replace present subject-matter on page 1435.

(6) Formula for Determining Comparative Economies of Flat and Hump Switching. Delete notes; formula only to remain. Page 1443.

(7) Comparative Freight Train Performance Charts. No change. Page 1447.

A–1

METHOD FOR THE DETERMINATION OF PROPER ALLOWANCE FOR MAINTENANCE OF WAY EXPENSE DUE TO INCREASED USE AND INCREASED INVESTMENT

In the present state of knowledge it is not recommended that following method be applied to a condition where the variation of traffic exceeds one-third above or below that of the base period. Used judiciously within this limitation the method will give reasonably accurate results if applied to a property sufficiently large or to a period of sufficient time to permit of the smoothing out of irregularities due to accidental conditions.

(I) ALLOWANCES FOR INCREASED INVESTMENT

Increases in investment are the net changes in Capital Account resulting from physical changes in a property. Portions of such increases may be due to acquisitions of lands, to enhanced costs of replacing in kind existing facilities, and to various other causes which cannot affect or augment the Maintenance requirements of the property. Other portions of the increases may represent substitutions of so-called permanent for temporary structures for purpose of reducing maintenance and still other portions cover numerous units of property in no wise similar in their maintenance requirements. From this it is apparent that Increased Investment is not a direct or proper measure of increased maintenance requirements. These requirements can be developed only from consideration of the property units actually represented by increases in investment in fixed property which for present purposes may be classified as follows:

(A) Way, including items chargeable to roadbed and track account.

(B) Structures, including bridges and buildings and the miscellaneous Items not otherwise classified.

(A) Investments—Way

Changes in the amount and character represented by increased investment in way are readily measured in track miles, but in order to determine the added maintenance requirement due to investment the different classes of trackage involved should be expressed in terms of equivalent main track by means of the equated track mile plan. Under this plan tracks may be weighted as follows:

1 mile of first main = 1.00 mile
1 " " each additional main = 0.80 "
1 " " sidings = 0.50 "

If on any given railroad the normal maintenance cost is known for a certain mileage, say 100 miles first main, 80 miles additional main and 30 miles sidings, and this is increased to 110 miles first main, 90 miles additional main and 40 miles sidings, the maintenance cost for the increased mileage but same traffic density will be in direct proportion to the equated mileages which for the example cited will be as:

$$\frac{202}{179} = 1.13$$

However, in applying this factor it must be remembered any difference of price levels making up Maintenance of Way cost must be taken into account, also differences in quality and methods used.

(B) Investments—Structures

The accounts in this general group are of such a nature that a comparison is virtually impossible and the increase in investment measured in dollars added to Capital Account, cannot be used directly as a measure of the changes in the amount and character of property units to be maintained and in view of this the estimated cost of reproduction now made by Interstate Commerce Commission in connection with Federal Valuation may be used instead of Investment Account. Reproduction costs in Federal Valuation were estimated on basis of 1914 prices and adjustments must be made for the difference in price level between 1914 and the period of normal maintenance selected as the Base Period and also reproduction cost of fixed property maintained as of valuation date must be adjusted for additions and deletions that have occurred between valuation date and the Base Period. With this information the relationship between reproduction cost of Base Period property and maintenance expenses may then be determined and assuming that cost of labor and material used in construction will vary from year to year at same rate as labor and material used in maintenance, this ratio can be used in different period without further adjustment providing general character of the property does not change materially.

As additions to the property between Base Period and period for which maintenance cost is desired, called the Comparison Period, will probably not be distributed between buildings, bridges, signal systems and other classes of structures in the same proportion as these classes made up the Base Period property, it is advisable to segregate both Base Period property and additions by Interstate Commerce Commission's primary accounts.

A complete analysis should be made of all changes—both debits and credits—in the investment accounts other than roadway and track between Base and Comparison Periods and eliminate from investment increases items having no effect upon maintenance. Where an intensive betterment program is involved, it will be necessary to segregate these items and to adjust the maintenance necessities on the basis of the relations between maintenance requirements of the betterments and of the items they replace.

Having determined from analysis of increases in the several investment accounts, items which should be eliminated or which may require special attention, increases in maintenance costs of structures may be determined as follows, using prices of 1914 as 1:00:

	Item	*Acct. Bridges*
1.	Engineering report, estimated reproduction cost of property as of valuation date (say 1916) at 1914 prices	$400,000
2.	Factor for increase in prices 1914 to base period	1.21
3.	Reproduction cost of 1916 property at base period prices (1) × (2)	484,000
4.	Added investment 1916 to base period	20,000

	Item	*Acct. Bridges*
5.	Average factor for increase in prices 1916 to base period: 1916 factor 1.10; base period factor 1.21. Factor for increase 1.21/1.10 or 1.10 whence average factor over period in which investment is being increased is	1.05
6.	Added investment 1916 to base period equated to base period prices (4) × (5)	21,000
7.	Reproduction cost of average amount of property maintained during base period at base period prices (3) plus (6)	505,000
8.	Base period maintenance expense	10,100
9.	Maintenance ratio (8) divided by (7)	0.02
10.	Added investment, base period to comparison period	85,000
11.	Portion of (10) which investigation indicates does not reflect additional maintenance requirements	25,600
12.	Portion of (10) involving additional maintenance (10) — (11)	59,400
13.	Average factor for increase in prices base period to comparison period: Base period factor 1.21, comparison period factor 2.06, factor for increase 2.06/1.21 or 1.70 whence average factor during investment increases is	1.35
14.	Added investment involving added maintenance base period to comparison period dequated to base period prices, (12) divided by (13)	44,000
15.	Factor for increase in property involving maintenance in comparison period: (14) divided by (7), plus 1.00	1.087
	If desired, the estimated cost of maintaining the additional property may be developed as follows:	
16.	Estimated cost of maintaining additional property at base period prices (14) × (9)	880
17.	Estimated cost of maintaining additional property at comparison period prices (16) × 1.70	1,496
18.	Estimated cost of maintaining base period property at comparison period prices (8) × 1.70	17,170
19.	Estimated cost of maintaining comparison period property at comparison period prices (17) plus (18)	18,666

Item 19 is subject to further adjustment, due to use, amount of which is developed under Section II "Use".

In the above analysis it has been assumed the growth of the property has been reasonably uniform and if so, above method is reasonably accurate. If the growth of the property has been small and distributed between roadbed and track and the different classes of structure with reasonable uniformity, a sufficiently close approximation of the allowance for increased investment may be obtained by using the equated mile as the measure of all fixed property.

(II) ALLOWANCES FOR INCREASED USE

It is well-recognized that the cost of Maintenance of Way and Structures becomes greater with increased use of traffic handled over a railway and that the converse also is true. While response to increase requirements are rarely immediate, nevertheless the relation between traffic handled and maintenance costs is reasonably constant if examined over a sufficient term of years. Extended analysis of the performances of numerous representative railways confirm this conclusion, but show that unlike transportation expense which varies almost directly, maintenance expense varies at a very much less rate than changes in traffic density.

The relation of maintenance expense to use is incapable of exact determination, but can be approximated by studying in detail properties as a whole and consists simply in separating maintenance charges not affected by use from those that are affected by use. This method was thoroughly tested out in the subsequent analysis of maintenance performances during the period of Federal Control.

The unit best adaptable to express usage of a railroad is the gross ton-mile but as gross ton-miles are made by freight locomotives, passenger locomotives, freight cars and passenger cars each of which produces a different effect upon maintenance it is necessary to equate them by weighing their effects and this may be done by assigning the following weights:

Freight car gross ton-miles	1.00
Passenger car gross ton-miles	1.00
Freight locomotives Gross ton-miles	2.00
Passenger locomotives Gross ton-miles	3.00

For any given railroad or district then the equated use made of the property is determined by multiplying the gross ton-miles made by above units by their factors and adding together to get total equated gross ton-miles.

Study was made of Interstate Commerce Commission records of Maintenance of Way and Structure expenses for all Class I railways for the three-year period ended June 30, 1917, and Table A shows ratio each account to total; per cent of each account that is affected by use; and affect of use of each account to total MW&S.

TABLE A—Affect of use on Maintenance of Way and Structure Accounts

1.	*Acct. No.* 2.	*Per Cent of Total MW&S Expense* 3.	*Per Cent Affected by Use* 4.	*Per Cent Total MW&S Expense Affected by Use* 5.
1. Superintendence	201	5.69	20	1.14
2. Ties	212	15.41	30	4.62
3. Rails	214	2.99	100	2.99
4. Other Track Material	216	4.52	100	4.52
5. Ballast	218	1.88	80	1.50
6. Roadway Maintenance	202	10.96		
7. Track laying and surfacing	220	25.91	55	14.25
8. Roadway Fences	221	.87		
9. Snow, Sand Fences, etc.	223	.11		
10. Crossings and Signs	225	1.30		
11. Roadway Machines	269	.45		
12. Small Tools and Supplies	271	1.13	40	.45
13. Removing Snow, Ice, etc.	272	1.76		
Sub-Total—Way		72.98	40.38	29.47
14. Bridge, Trestles and Culverts	208	7.38	10	.74
15. Tunnels and Subways	206	.32	10	.03
16. Elevated Structures	210	.01		
17. Station and Office Buildings	227	3.93		
18. Roadway Buildings	229	.53		
19. Water Stations	231	1.31	10	.13
20. Fuel Stations	233	.53	15	.08
21. Shops, Enginehouses	235	2.45	10	.25
22. Grain Elevators	237	.06		
23. Storage Warehouse	239	.01		
24. Wharves and Docks	241	.61	10	.06
25. Coal and Ore Wharves	243	.55	10	.06
26. Gas Power Plants	245	.01		
27. Power Plant Buildings	253	.07		
28. Power Sub-Station Buildings	255	.01		
29. Miscellaneous Structures	265	.01		
Sub-Total—Structures		17.87	7.55	1.35
30. Underground Power Tubes	204	*		
31. Power Plt. Dams and Pipe Lines	251	*		
32. Power Transmission Systems	257	.03		
33. Power Distribution Systems	259	.25		
34. Power Line Poles and Fixtures	261	.03		
35. Underground Conduits	263	*		

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* Less than .01 per cent.

	1.	Acct. No. 2.	*Per Cent of Total MW&S Expense* 3.	*Per Cent Affected by Use* 4.	*Per Cent Total MW&S Expense Affected by Use* 5.
	Sub-Total—Power Facilities		0.31		
36.	Telegraph & Telephone Lines	247	1.11		
37.	Signals and Interlockers	249	2.67	30	0.80
	Sub-Total—Wire and Signal Systems		3.78	21.16	0.80
38.	Shop Machinery	302	2.76	40	1.10
39.	Power Plant Machinery	304	.44	5	.02
40.	Power Sub-Station apparatus	306	.03		
	Sub-Total—M.ofE. Plant Maint.		3.23	34.67	1.12
41.	Paving	267	.05		
42.	Assessments Public Improvs.	273	.07		
43.	Injuries to Persons	274	.73	50	.37
44.	Insurance	275	.61		
45.	Stationery and Printing	276	.20	10	.02
46.	Other Expenses	277	.17		
	Sub-Total—Miscellaneous		1.83	46.92	.39
	Totals		100.00		33.13

In order therefore to determine effect of use on total MW&S account the following steps are necessary:

1. Select Base Period in which both traffic and expense of MW&S account are normal.
2. Select Comparison Period for which MW&S account is desired.
3. Compile equated gross ton miles separately for Base and Comparison Periods.
4. Determine equated track mileage maintained separately for Base and Comparison Periods.
5. Determine equated gross tons per equated track mile for Base and Comparison Periods by dividing (3) by (4).
6. Develop difference in traffic density per equated track mile for the two periods from (5).
7. Set up Base Period MW&S expense per table A and determine effect of use.
8. Factor for difference in use will be 1.00 plus percent traffic increase shown by (6) × per cent effect shown in (7).

As an example of the application of the above if we assume that traffic density increased 30 per cent and for the property in question the use factor was found to be 40 per cent instead of 33.13 per cent as shown in table A, then the factor for increased use will be

$$1.00 + (0.30 \times 0.40) = 1.12 \text{ or,}$$

an increase in MW&S total account of 12 per cent.

The total maintenance expense due to change in both investment and use will then be assuming no change in price levels and that normal maintenance expenditures at Base Period prices amounted to $237,000 for Way, $10,100 for Structures and that there has been a 30 per cent increase in traffic:

Investment:			
Way	237,000 × 1.13 × 1.70 =	$455,277	
Structures	10,100 × 1.70 + 1496 =	18,666	$473,943
Use: 473,943 × 0.12			56,873
Total annual maintenance for Comparison Period			$530,816

The foregoing relates to allowances for increased use. However, in the event that it is desired to continue comparisons, from year to year, proper ratios to the base period Use Factor can be maintained during periods of Decreased Use, by applying the formula in the following form:

$$e = E\left(\frac{1}{1+\frac{T-t}{t}A}\right)$$

where

e = expense of original base period
E = expense of new base period
t = traffic density of original base
T = traffic density of new base
A = percentage of expenses which are direct at traffic density

A–2

THE COST OF STOPPING AND STARTING TRAINS

A method of estimating the cost of stopping and starting trains has been determined from an analysis of the expense items incident to train service that might properly be considered. These accounts and the basic factors by which they are related to the problem together with detail discussion, tables, charts and examples are shown in Appendix A of Report of Committee XXI—Economics of Railway Operation, pages 473 to 512, Vol. 28, Proceedings.

The cost of starting and stopping freight trains is made up of the following items:

(A)	Wages of train enginemen—Account	No. 392
	Wages of trainmen—Account	No. 401
	NOTE.—These two items are only to be used when train is on an overtime basis and their cost is computed by multiplying time lost in decelerating plus time at stop plus time accelerating to speed when deceleration began by the overtime rate per minute.	
(B)	Fuel for freight locomotives—Account	No. 394
(C)	Water for freight locomotives—Account	No. 397
(D)	Lubricants for freight locomotives—Account	No. 398
(E)	Other supplies for freight locomotives—Account	No. 399
(F)	Locomotive Repairs—Account	No. 308
	" Depreciation—Account	No. 309
	" Retirements—Account	No. 310
(G)	Freight train car repairs—Account	No. 314
	" " " depreciation—Account	No. 315
	" " " retirements—Account	No. 316

If cost of stopping passenger trains is desired appropriate expense for passenger trains should be substituted in above items.

Coal lost in making a train stop is made up of the following:

(a) Coal required to restore kinetic energy in train equivalent to energy destroyed by brakes in stopping.
(b) Difference in coal required by the stop and the non-stop trains to do the work done by the non-stop train between the point at which stop train starts to decelerate and the point at which it regains the speed of the non-stop train.
(c) Coal consumed by the stop train while standing at the stop.
(d) Coal required for the extra steam used by the non-stop train in brake application, in all other auxiliaries, and that lost through the safety valves.
(e) Coal required due to slipping of drivers in starting and decrease in boiler efficiency at stops.

It is apparent that coal consumed in stopping and starting a train and also time consumed will vary with the grade. If level grade is taken as normal then both coal and time will be less for down-grade and more for up-grade. The total pounds of coal lost in stopping and starting a train based on coal having 14000 b.t.u. per pound for items a, b, c, d, and e, is:

Level Tangent Track:

$$P' = \frac{Ty}{1{,}000{,}000}\left[V^2(p' - p''')(70 - DR) + M^2\ (70p''' + 1.16RMp'')\right] + xt$$

Descending Grade:

$$P' = \frac{Ty}{1{,}000{,}000}\left[V^2(p' - p''')(70 + 20DK - DR) + M^2\ (70p''' + 1.16RMp'' - 23.2MGp'')\right] + xt$$

Ascending Grade:

$$P'' = \frac{Ty}{1{,}000{,}000}\left[V^2(p' - p''')(70 + 20DK - DR) + M^2\ (70p''' + 1.16RMp'' + 23.2MGp'')\right] + xt$$

where,

$D =$ a constant, which when multiplied by V^2 gives the distance traveled by the train from point of initial brake application to stop. Its value for different grades and train consist is given in Table 1.

$G =$ per cent of average grade over the accelerating distance of stop train. All negative values of G greater than the maximum given by placing:

$$G = \frac{70(M^2 \text{ or } V^2) + 1.16\ RM}{23.2\ M^2}$$ are made equal to the value thus given.

$K =$ maximum per cent of down grade over the decelerating distance of stop train that will not supply excess energy. It is equal to the average per cent down grade traversed by the stop train between V and zero speeds whenever this average does not exceed the maximum per cent as given by the following formula:

$$K = \frac{R}{20}\ 3.5\left(\frac{M^2 - V^2}{DV^2}\right)$$ in which all negative values of $3.5\left(\frac{M^2 - V^2}{DV^2}\right)$ are made equal to zero.

$M =$ speed of the non-stop train equal to the permissible speed or the average speed maintained over that part of the road by trains similar to the stop train.

$P =$ total pounds of coal lost by stopping and starting freight trains on level tangent track.

$P' =$ total pounds of coal lost by stopping and starting freight trains on a descending grade.

$P'' =$ total pounds of coal lost by stopping and starting freight trains on an ascending grade.

$p' =$ pounds of coal having 14,000 B.t.u. per pound required to furnish 1,000,000 foot-pounds of energy at the drawbar at "s" speed. For other B.t.u. values multiply by their ratio to 14,000. For coal having 14,000 B.t.u.—$p' = 1.50 + .00011\ (25 - s)^3$.

$p'' =$ the difference in pounds of coal having 14,000 B.t.u. per pound required to furnish 1,000,000 foot pounds of energy at the drawbar at speeds of m and M. For other B.t.u. values multiply by their ratio to 14,000. For coal having 14,000 B.t.u., $p'' = .00011\ [(25 - m)^3 - (25 - M)^3]$.

$p''' =$ the difference in pounds of coal having 14,000 B.t.u. per pound required for furnishing 1,000,000 foot-pounds of energy at the drawbar at the speeds of $\frac{M + S}{2}$ and M.

$R =$ pounds of car resistance per ton of train back of tender; it is equal to 3.82 for trains averaging 50 tons or over per car and 6.00 for trains averaging under 50 tons per car.

$S =$ speed to which train must be accelerated to restore destroyed energy.

$s =$ average speed of train in accelerating to S speed. Values for s are given in Table 2.

$T =$ total weight of stop train in tons back of tender.

$t =$ time train stands at stop in minutes.

$V =$ speed in miles per hour at which initial brake application is made, on stop train.

$x =$ a constant, the value of which has been determined to be 0.10 per square foot of locomotive grate area for all atmospheric temperatures of 40° Fahr. or over, and 0.115 under 40°.

$y =$ a constant reflecting decreases or increases in over-all efficiency of the locomotive due to grade or of a saturated locomotive as compared to a superheated locomotive. For grade effect on efficiency of superheated locomotives $y = 1 \pm .20\,G$ and $1.23 \pm .20\,G$ for saturated. These values of y are based on coal having 14,000 B.t.u. per pound and for other values multiply these results by ratio of B.t.u.'s in coal used to 14,000.

TABLE 1—Values of *D* for different grades and different weights of cars

Average per cent grade traversed by train in stopping after initial brake application	*50 tons and over Brake Application*		*Under 50 tons Brake Application*	
	Service	*Emergency*	*Service*	*Emergency*
+ to — .25%	3.000	0.270	1.000	0.090
— .25 " — .50	3.515	0.316	1.165	0.105
— .50 " — .75	4.030	0.363	1.330	0.120
— .75 " —1.00	4.500	0.405	1.500	0.135
—1.00 " —1.25	4.995	0.450	1.665	0.150
—1.25 " —1.50	6.490	0.584	1.830	0.165

NOTE.—+ = up grade — = down grade curvature to be used as equivalent up grade, each degree of curvature being equal to .04 per cent grade.

TABLE 2—Average speed of freight trains in accelerating

M. or S. Speed Miles per hour	*m Speed Miles per hour*	*s Speed Miles per hour*
0 to 5	0.63 M	0.63 S
5 to 10	0.65 M	0.65 S
10 to 15	0.72 M	0.72 S
15 to 30	0.73 M	0.73 S
30 to 50	0.75 M	0.75 S

Tests made with high-speed Mikado engines show that total average time lost in decelerating and accelerating a freight train is on level track for:

Trains consisting of empty cars = 4.0 minutes
Trains consisting of loaded cars = 4.1 minutes

This time increases on ascending and decreases on descending grades at rate of 12 seconds per one per cent of grade.

In addition to above, time is also lost in releasing the air, this time having been found to be:

2 minutes for 25 car train
3 minutes for 50 car train
4 minutes for 75 car train
5 minutes for 100 car train

The time consumed by stop train in decelerating plus time at stop plus time accelerating to speed of non-stop train less time consumed by non-stop from point of deceleration to point where stop train has accelerated to speed of non-stop train represents additional time of stop train and should be used in computing wages if on overtime basis, lubricants and other elements of cost affected by time.

The other items of expense are arrived at as follows:

Water	One gallon of water is used per pound of coal. Multiply this by cost of water on district considered.
Lubricants	Multiply time lost making stop by cost of lubricants per train hour for service involved.
Other supplies for freight train locomotives	Multiply time lost making stop by 30 per cent of cost chargeable to account No. 399.
Locomotive repairs, depreciation and retirements	Determine cost of ownership based on repairs, interest, depreciation and retirements by dividing the sum of interest on depreciated value of serviceable locomotives at 5¾ per cent per annum and the total of accounts 308, 309 and 310 for a representative period by number of serviceable locomotives. If there is a surplus of power then cost of ownership should be multiplied by ratio of cost of repairs to the total, thus eliminating interest, depreciation and retirements.
Freight train car repairs, depreciation and retirements accounts 314, 315, 316.	Cost of ownership of cars may be taken at the per diem charge of $1.00 per day. If there is a surplus of cars cost of repairs should be determined and the per diem charge of $1.00 multiplied by ratio of repairs to per diem charge thus eliminating interest, depreciation and retirements.

Appendix B

(6) EFFECT OF VOLUME OF TRAFFIC ON RAILWAY OPERATING EXPENSES

S. W. Fairweather, Chairman, Sub-Committee; G. W. Hand, P. R. Leete, J. F. Pringle, John Worley.

Your Committee presents the following report regarding this subject:

INFLUENCE OF TRAFFIC DENSITY ON TRANSPORTATION EXPENSES

The extent to which transportation expenses are influenced by changes in traffic density has been studied for each district of the U.S. for the years 1928 to 1932 inclusive. As an aid to judgment the expenses for each of the principal primary accounts were analyzed graphically, and for this purpose prices and wages were adjusted to a uniform basis as of 1926, and the total gross ton miles, passenger and freight, including engines and tenders was used as the basis of traffic density. The actual transportation expenses, i.e., the gross total for each year was used; transportation for investment credit was not deducted. The characteristics of each account, as determined by analysis were combined by assigning to each a weight proportionate to its percentage of the total of transportation expenses. Since a distinct variation was found in the general characteristics of each district of the U.S. it was deemed advisable to present the results of each district separately.

The results of the study have been consolidated into the following tables, which show the extent to which each main primary account is variable with traffic at various traffic densities and also the weighted average for the total transportation account:

Class I U.S. Roads—Eastern District—1928–1932 Inclusive

PROPORTION VARIABLE OF TRANSPORTATION EXPENSE* AT INDICATED LEVELS OF TRAFFIC DENSITY

	Gross Ton Miles per Mile					
	5000	6000	7000	8000	9000	10000
	%	%	%	%	%	%
Superintendence	84.7	86.9	88.6	89.3	90.9	91.7
Despatching Trains	57.1	61.5	65.1	68.1	70.6	72.7
Station Employees	96.8	97.3	97.7	98.0	98.2	98.4
Station Supplies and Expenses	5.3	6.3	7.3	8.3	9.2	10.1
Yardmasters and Clerks	91.7	93.0	93.9	94.6	95.2	95.7
Yard Conductors and Brakemen	133.1	126.1	121.6	118.4	116.1	114.2
Yard Enginemen	127.7	122.1	118.4	115.7	113.7	112.2
Fuel for Yard Locomotives	125.5	120.4	117.0	114.6	112.7	111.3
Enginehouse—Exp.—Yard	97.5	97.9	98.2	98.4	98.6	98.7
Train Enginemen	116.9	113.7	111.5	110.2	108.7	107.8
Fuel for Train Locomotives	89.8	91.3	92.5	93.4	94.1	94.6
Water for Train Locomotives	30.4	34.4	38.0	41.2	44.1	46.7
Enginehouse—Exp.—Train	77.5	80.5	82.8	84.6	86.1	87.3
Trainmen	91.8	93.1	94.0	94.7	95.3	95.7
Train Supplies and Expenses	27.3	31.0	34.4	37.5	40.3	42.9
Signal and Interlocker Opern.	65.7	69.7	72.9	75.4	77.5	79.3
Crossing Protection	21.3	24.5	27.5	30.2	32.7	35.1
Operating Floating Equipment	80.0	82.8	84.8	86.5	87.8	88.9
Loss and Damage—Freight	62.2	66.3	69.7	72.4	74.7	76.7
Injuries to Persons	96.2	96.8	97.2	97.6	97.8	98.0
All Other Accounts	51.9	56.4	60.2	63.3	66.0	68.3
Total	84.9	87.1	88.7	90.0	91.0	91.8

*Rail Line before deduction of "Transportation for Investment Credit."

CLASS I U.S. ROADS—SOUTHERN DISTRICT—1928–1932 INCLUSIVE

PROPORTION VARIABLE OF TRANSPORTATION EXPENSE† AT INDICATED LEVELS OF TRAFFIC DENSITY

	Gross Ton Miles per Mile				
	3000	4000	5000	6000	7000
	%	%	%	%	%
Superintendence	57.1	63.9	68.9	72.7	75.6
Despatching Trains	84.7	88.1	90.2	91.7	92.8
Station Employes	100.0	100.0	100.0	100.0	100.0
Station Supplies and Expenses	16.1	20.3	24.2	27.7	30.9
Yardmasters and Clerks	70.0	75.7	79.5	82.4	84.5
Yard Conductors and Brakemen	122.4	115.9	112.4	110.1	108.5
Yard Enginemen	113.5	109.8	107.7	106.3	105.4
Fuel for Yard Locomotives	122.7	116.1	112.5	110.2	108.6
Enginehouse—Exp.—Yard	76.2	81.0	84.2	86.5	88.2
Train Enginemen	95.5	96.6	97.3	97.7	98.0
Fuel for Train Locomotives	100.0	100.0	100.0	100.0	100.0
Water for Train Locomotives	34.4	41.2	46.7	51.2	55.1
Enginehouse—Exp.—Train	84.4	87.8	90.0	91.5	92.7
Trainmen	100.0	100.0	100.0	100.0	100.0
Train Supplies and Expenses	48.1	55.3	60.7	65.0	68.4
Signal and Interlocker Opern.	26.7	32.7	37.7	42.1	45.9
Crossing Protection	31.0	37.5	42.9	47.4	51.2
Operating Floating Equipment	13.6	17.4	20.8	24.0	26.9
Loss and Damage—Freight	41.9	49.0	54.5	59.0	62.7
Injuries to Persons	61.7	68.2	72.8	76.3	78.9
All Other Accounts	82.8	86.5	88.9	90.6	91.8
Total	88.2	90.9	92.5	93.7	94.5

†—Rail Line before deduction of "Transportation for Investment Credit."

CLASS I U.S. ROADS—WESTERN DISTRICT—1928–1932 INCLUSIVE

PROPORTION VARIABLE OF TRANSPORTATION EXPENSE‡ AT INDICATED LEVELS OF TRAFFIC DENSITY

	Gross Ton Miles per Mile			
	2000	3000	4000	5000
	%	%	%	%
Superintendence	73.7	80.8	84.8	87.5
Despatching Trains	100.0	100.0	100.0	100.0
Station Employees	69.6	77.4	82.1	85.1
Station Supplies and Expenses	7.7	11.1	14.3	17.2
Yardmasters and Clerks	80.0	85.7	88.9	90.9
Yard Conductors and Brakemen	100.0	100.0	100.0	100.0
Yard Enginemen	100.0	100.0	100.0	100.0
Fuel for Yard Locomotives	100.0	100.0	100.0	100.0
Enginehouse—Exp.—Yard	68.3	76.4	81.2	84.3
Train Enginemen	94.1	96.0	97.0	97.6
Fuel for Train Locomotives	83.9	88.6	91.2	92.9
Water for Train Locomotives	29.6	38.7	45.7	51.3
Enginehouse—Exp.—Train	78.3	84.4	87.8	90.0
Trainmen	76.2	82.8	86.5	88.8
Train Supplies and Expenses	41.2	51.2	58.3	63.6
Signal and Interlocker Operation	19.0	26.1	32.0	37.0
Crossing Protection	29.6	38.7	45.7	51.3
Operating Floating Equipment	70.6	78.3	82.8	85.7
Loss and Damage—Freight	47.4	57.4	64.3	69.2
Injuries to Persons	51.9	61.8	68.3	72.9
All Other Accounts	61.5	70.6	76.2	80.0
Total	74.6	81.5	85.5	88.0

‡—Rail Line before deduction of "Transportation for Investment Credit."

These tables permit of an estimate being made of the influence of a change in traffic density upon the transportation expenses of a railway. The steps to permit of such a forecast are as follows:

1. Set out, by primary accounts, the transportation expenses for the base period.
2. Determine the traffic density in millions of gross ton miles (freight and passenger) per mile of line for the base period and for the desired period.
3. From the appropriate table determine the percent to which each primary account is variable with traffic, interpolating when necessary.
4. Multiply the percentage of each primary account which is variable with traffic by the percentage which the same account is of the total transportation expenses, thus obtaining a weighted average percentage variable with traffic for the total transportation expenses.
5. Determine the expense under the new conditions by the application of the formula,

$$E_1 = E_b\left[(1 - V) + \frac{D_1 V}{D_b}\right]$$

where E_1 = Desired transportation expense estimate.
E_b = Transportation expense of the base period adjusted to the same price and wage level as E_1.
D_b = Traffic density corresponding to E_b.
D_1 = Traffic density corresponding to E_1.
V = Decimal factor of variability at traffic density D_b.

The result will be the estimate of total transportation expenses.

The method may be used to determine the expense either under conditions of increased or decreased traffic as compared with the base period, but it should be used with caution. For instance, it cannot be expected to yield consistent results either in the case of a small property or in the case of sudden temporary changes in traffic density, nor should it be applied to a condition where the capacity of the line to carry the indicated traffic is in question.

This report is offered as information.

Appendix C

(7) OPERATION WITH REDUCED NUMBER OF MAIN TRACKS

B. J. Schwendt, Chairman, Sub-Committee; B. T. Anderson, J. H. Dyer, J. S. McBride, C. P. Richmond, H. F. Schryver.

ECONOMIC ADVANTAGE OF CONVERTING DOUBLE TRACK TO SINGLE TRACK

East and North Railroad

Continuing the study of the effect upon roadway maintenance and operating costs of the conversion of double track to single track, your Committee presents this report to show the relation of costs in maintenance of way and operation for comparative years of double-track operation and single-track operation on a 32-mile line of double track on the East and North Railroad, converted to single track in February, 1933, and on a 28-mile line of double track, converted to single track in December, 1932. As the operating, track, and signal conditions were different on each of the two sections of railroad, this report has been divided into two parts; the first one, the 32-mile conversion, being shown as Fig. 1 and Fig. 2; the 28-mile conversion, as Fig. 3 and Fig. 4.

32-Mile Study

Traffic

	Average Number of Trains Between "B" and "D"			
Period	*Passenger*	*Thru Freight*	*Local Freight*	*Total*
1921–1931	10	4	1	15
1932–1934	4	2	0	6

The heaviest power used before and after the change consisted of the class of engines with 77,800-lb. tractive effort. The present traffic between "B" and "D" is probably as heavy as it will be five years hence, at least not over 10 per cent increase is expected. It will be noted that the single track is now receiving less traffic than each track received during double-track operation.

Operation of Trains

Trains were and continue to be operated by timetable, train orders, and manual block. Maximum speed is 60 miles per hour for passenger trains and 35 miles per hour for freight trains. This line is one of the emergency detour routes for a main trunk line where traffic is heavy.

Original Track Plan—Double Track

Fig. 1 shows the original double-track territory, "A" to "D," a distance of 41 miles. The double track extends easterly an additional 19 miles to the terminal of the division. There is a mechanical interlocking plant at "A" and at "B," each operated 24 hours, 7 days a week. At "A" there is a railroad crossing at grade with another railroad, protected from the tower at "A." "B" is a junction point for a diverting route.

There were two automatic block signals, three ARA flashlight highway grade crossing signals, and two highway grade crossings provided with automatic bells.

Present Track Plan—Single Track

Fig. 2 shows the portion of the railroad from "B" to "D," a distance of 31.78 miles converted to single-track operation. At "C" the track retained for single track was thrown from track 1 to track 2. A portion of the track to be abandoned was retained and connected for sidings at 3 locations, 2 of which are of 55-car capacity and one of 16-car capacity. The present end of the double track is at the crossover at "B" controlled from tower 231. Maximum degree of curvature is 3 degrees. Grades are from 0.04 per cent to 1.00 per cent.

The changes in the original double-track plan, Fig. 1, were as follows:

(a) Installed 5 turnouts, removed 3 turnouts
(b) Relocated 2 crossovers, removed 3 crossovers
(c) Relocated 600 feet of main track at "C"
(d) Converted 31.78 miles of main track to single track
(e) Retained 3.38 miles of main track as sidings and sidetrack
(f) Abandoned and removed 28.40 miles of main track.
(g) Removed 2 automatic block signals
(h) Two distant switch signals were installed for facing point switches created by the single track on descending grade.

EFFECT UPON MAINTENANCE AND OPERATING COSTS OF CONVERTING DOUBLE TRACK TO SINGLE TRACK

Total Annual Reduction in Costs

(I) On the basis of present-day costs—deferred maintenance		
(a) Decreased cost of maintenance		
Difference in annual costs of maintenance of main track (ordinary routine repairs)*	$12,006	
Estimated annual service cost of tracks and bridges (extraordinary repairs)*	19,554	
Total estimated annual saving in roadway maintenance cost ($993 per mile of track converted to single track)		$31,560
(b) Increased cost of operation		
Increased annual cost of blocking trains		250
(c) Net total estimated reduction in annual cost		$31,310
(II) On the basis of estimated normal maintenance cost		
(a) Decreased cost of maintenance		
Estimated annual saving in maintenance of main track (ordinary routine repairs)	$33,466	
Estimated annual service cost of tracks and bridges (extraordinary repairs)	19,554	
Total estimated annual saving in roadway maintenance cost (or $1,668 per mile of track converted to single track)		$53,020
(b) Increased cost of operation		
Increased annual cost of blocking trains		250
(c) Net total estimated reduction in annual cost		$52,770

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* Repairs are divided, for the purpose of this study, into two classes:
Ordinary routine repairs, day-to-day renewals, partial replacements, and adjustments.
Extraordinary repairs, those made periodically at longer intervals such as rail, tie, bridge, and ballast renewals, etc.

EXPENDITURES POSTPONED ACCOUNT OF SINGLE TRACK OPERATION

Tie Renewals

There were 19,500 untreated ties in the track abandoned with an average service of 10 years. If double-track operation had been continued, it would have been necessary to replace these ties within 5 years at an estimated cost of $32,000.

Rail Renewals

It will be noted that the track retained for single-track operation changed from track 1 to track 2. This was done to take advantage of the track in best condition for continued operation. If double-track operation had been continued, it would have been necessary to renew 5 miles of track (100-lb.–107-lb. rail) with 107-lb. worn rail within 3 years at an estimated cost of $14,700.

Bridge Renewals

It would have been necessary to renew bridge ties and timbers on some of the bridges within 3 years at an estimated cost of $4,500.

Taxes do not appear in the savings for the reason that the property within the 5-rod line of location is not taxed, provided it is not used for other than railroad purposes.

STATEMENT OF CAPITAL COSTS

Actual Cost of Retiring and Making Track Changes

	R. & E.	*O. E.*	*P. & L.*	*Total*
Track and other changes	$11,627			$11,627
Operating expenses		$2,833		2,833
Cash expenditure	$11,627	$2,833		$14,460
Retirement of track	Cr. 326,000		$326,000	
Cost of removing track (28.4 miles)			13,000	13,000
Salvage (28.4 miles)			Cr. 162,674	Cr. 162,674
Totals	Cr. $314,373	$2,833	$176,326	Cr. $135,214

The amount $326,000, retirement of track, credited to R. & E. represents the carrier's investment in the property, including additions and betterments to the date of the change.

The retirement and removal of 31.78 miles of track resulted in a net return to the railroad of $162,674 for the salvage value of the material recovered and made available for use at other locations.

SUMMARY

Converting 31.78 miles of double track to single track on the East and North Railroad resulted in the following changes in capital, maintenance of way, and operating costs:

First—Expenditures and credits for track and other changes

(a) Required a cash expenditure of	$14,460
(b) Reduced capital account by	314,373
(c) Showed charge to profit and loss of	176,326
(d) Showed credit for salvage of	162,674
(e) Resulted in net credit of	135,214

Second—Decreased cost in maintenance of track, bridges, and signals		
Present-day costs		
(a) Actual annual reduction in maintenance cost of main track (ordinary repairs)	$12,006	
(b) Estimated annual saving in service cost for main track, bridges, and signals (extraordinary repairs)	19,554	
(c) Total estimated annual saving in roadway maintenance (deferred maintenance)		$31,560
Normal maintenance		
(d) Estimated annual saving in maintenance cost of main track (ordinary repairs)	$33,466	
(e) Estimated annual saving in service cost of main track, bridges, and signals (extraordinary repairs)	19,554	
(f) Total estimated annual saving in roadway maintenance cost (normal year)		$53,020
Third—Increased cost of operation		
Increased annual cost of blocking trains		250

Fourth—Return on the cash expenditure

(a) On the basis of present-day costs, shows a total annual reduction in cost of maintenance and operation of $31,310 on the cash expenditure of $14,460, or 217 per cent of the cash expenditure.

(b) On the basis of normal maintenance, shows a total annual reduction in cost of maintenance and operation of $52,770 on the cash expenditure of $14,460, or 365 per cent of the cash expenditure.

28-Mile Study

Traffic

Average Number of Trains Between "A" and "F"

Period	Between "A" and "C" P	F	T	Between "C" and "D" P	F	T	Between "D" and "G" P	F	T	Between "E" and "F" P	F	T
1922–1927	6	14	20									
1928–1932	2	14	16									
1933–1934	0	10	10									
1922–1928				19	14	33	15	6	21			
1929–1932				12	14	26	8	4	12			
1933–1934				8	10	18	8	4	12			
1922–1924										6	6	12
1925–1929										4	6	10
1930										2	4	6
1931–1934										0	4	4

$P =$ Passenger, $F =$ Freight, $T =$ Total.

In general the same class of power has been used since 1926 as follows:

Between "A" and "D," tractive effort, 53,900 lb.
Between "D" and "F," tractive effort, 34,700 lb.

The present traffic between "A," "F," and "G" is probably as heavy as it will be 5 years hence, at least not over 10 per cent increase is expected.

Operation of Trains

Before the change, trains were operated by timetable, train order, and manual block, and by automatic block signals between "A" and "B" and between "C" and "D". Trains are now operated on single track by timetable, train orders, and manual block. Maximum speed permitted between "A" and "D" is 50 miles per hour for passenger trains and 35 miles per hour for freight trains. Maximum speed permitted between "D," "F" and "G" is 35 miles per hour for passenger and freight trains.

Original Track Plan—Double Track

Fig. 3 shows the original double-track plan between "A" and "F," a distance of 36 miles. This line is crossed at grade by another railroad at 4 locations. Seven mechanical interlocking plants and one automatic junction were in service. Five highway grade crossings were protected with ARA flashlight signals, while 7 highway grade crossings were protected with bells.

Present Track Plan—Single Track

Fig. 4 shows the present single track with a short 1.4-mile section of double track left in service between "C" and "D" where interchange, yard and switching movements are involved.

The changes in the original double-track plan, Fig. 1, were as follows:

(a) Installed 10 turnouts, relocated 6 turnouts and removed 6 turnouts
(b) Removed 7 crossovers, 9 crossing frogs and one set No. 7 double slip switches
(c) Converted 28.35 miles of main track to single track
(d) Retained 8.25 miles of main track as passing siding and running track
(e) Abandoned 19.6 miles of main track
(f) Abandoned one 24-lever mechanical interlocking plant
(g) Abandoned 26 automatic block signals between "A" and "B" and "C" and "D"
(h) Abandoned 16 interlocking signals, at 4 junction points, 3 ground machines, and 2 distant switch signals

The portion of the track abandoned has not been removed.

Effect Upon Maintenance and Operating Costs of Converting Double Track to Single Track

Total Annual Reduction in Costs

(I) On the basis of present-day costs—deferred maintenance

(a) Decreased cost of maintenance

Difference in annual costs of maintenance of main track (ordinary routine repairs)	$28,194	
Difference in annual costs of maintenance of signals (ordinary routine repairs)	3,900	
Total actual annual saving in maintenance cost (ordinary routine repairs) ($1132 per mile of track converted to single track)		$32,094
Estimated annual service cost of tracks, bridges, and signals (extraordinary repairs)		20,925
Total estimated annual saving in roadway maintenance cost ($1870 per mile of track converted to single track)		$53,019
(b) Less increased cost of operation		6,068
(c) Net total estimated reduction in annual cost		$46,951

(II). On the basis of estimated normal maintenance costs		
(a) Decreased cost of maintenance		
Estimated annual saving in maintenance of main track (ordinary routine repairs)	$37,748	
Difference in annual costs of maintenance of signals (ordinary routine repairs)	3,900	
Total estimated annual saving in maintenance cost (ordinary routine repairs) ($1469 per mile of track converted to single track)		$41,648
Estimated annual service cost of tracks, bridges, and signals (extraordinary repairs)		20,925
Total estimated annual saving in roadway maintenance cost ($2207 per mile of track converted to single track)		$62,573
(b) Less increased cost of operation		6,068
(c) Total estimated reduction in annual costs		$56,505

Expenditures Postponed Account of Single Track Operation

Tie Renewals

There were 24,000 No. 2 untreated ties in the track abandoned with an average service of 10 years. If double-track operation had been continued, it would have been necessary to replace these ties within 5 years at an estimated cost of $40,000.

Rail Renewals

If double-track operation had been continued, it would have been necessary to renew 3 miles of track (78-lb.–80-lb. rail) with 107-lb. worn rail within 3 years at an estimated cost of $14,100.

Ballast Renewals

Likewise, it would have been necessary to renew 6 miles of track with gravel ballast within 3 years at an estimated cost of $16,200.

Bridge Renewals

It would have been necessary to renew bridge ties and timbers on bridges within 3 years at an estimated cost of $900.

Statement of Capital Costs

Cost of Retiring and Making Track and Signal Changes

	R. & E.	*O. E.*	*P. & L.*	*Total*
Track and other changes	$8,647			$8,647
Operating expenses		$9,300	$2,931	12,231
Cash expenditure	$8,647	$9,300	$2,931	$20,878
Retirement of track	Cr. 248,194		248,194	
Salvage of track		Cr. 62	Cr. 774	Cr. 836
Totals	Cr. $239,547	$9,238	$250,351	$20,042
Estimated cost of removing track retired			8,800	8,800
Estimated credit for salvage of material recovered			Cr. 69,470	Cr. 69,470
Totals	Cr. $239,547	$9,238	$189,681	Cr. $40,628

NOTE.—Salvage for and cost of removing ties, rail, and other track material has been estimated for the reason that the abandoned track has not been removed.

Summary

Converting 28.35 miles of double track to single track on the East and North Railroad resulted in the following changes in capital, maintenance of way, and operating costs:

First—Expenditures and credits for track and other changes

(a)	Required a cash expenditure of	$20,878
(b)	Reduced capital account by	239,547
(c)	Showed estimated charge to profit and loss of	189,681
(d)	Showed estimated credit for salvage of	69,470
(e)	Resulted in estimated net credit of	40,628

Second—Decreased cost in maintenance of track, bridges, and signals

Present-day costs			
(a)	Actual annual reduction in maintenance cost of main track (ordinary repairs)	$28,194	
(b)	Actual annual reduction in maintenance cost of signals (ordinary repairs)	3,900	
(c)	Estimated annual saving in service cost of main track, bridges, and signals (extraordinary repairs)	20,925	
(d)	Total estimated annual saving in roadway maintenance cost (deferred maintenance)		$53,019
Normal maintenance			
(e)	Estimated annual saving in maintenance cost of main track (ordinary repairs)	$37,748	
(f)	Estimated annual saving in maintenance cost of signals (ordinary repairs)	3,900	
(g)	Estimated annual saving in service cost of main track, bridges, and signals (extraordinary repairs)	20,925	
(h)	Total estimated annual saving in roadway maintenance cost (normal year)		$62,573

Third—Increased cost of operation

(a)	Increased annual cost of operation account of interference to trains	$5,840	
(b)	Increased annual cost of operation account of additional operator	1,893	
(c)	Total increased annual cost of operation		$7,733
(d)	Less decreased annual cost account of elimination of one signal station operator		1,665
(e)	Net increased annual cost of operation		$6,068

Fourth—Return on the cash expenditure

(a) On the basis of present-day costs, shows a net total annual reduction in cost of maintenance and operation of $46,951 on the cash expenditure of $20,878, or 225 per cent of the cash expenditure.

(b) On the basis of normal maintenance, shows a net total annual reduction in cost of maintenance and operation of $56,505 on the cash expenditure of $20,878, or 271 per cent of the cash expenditure.

Increased Density of Traffic

The ability and economy of handling a future increase in traffic with single-track operation was studied. This study revealed that traffic equal to the heaviest traffic in recent years (1921–1931), could be more economically handled with single-track operation and improved signal facilities, such as automatic block or C.T.C., than with double-track operation.

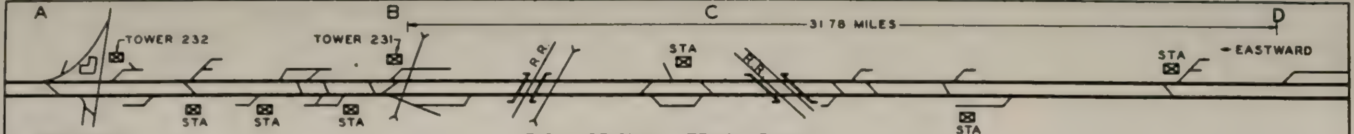

FIG 1 ORIGINAL TRACK PLAN

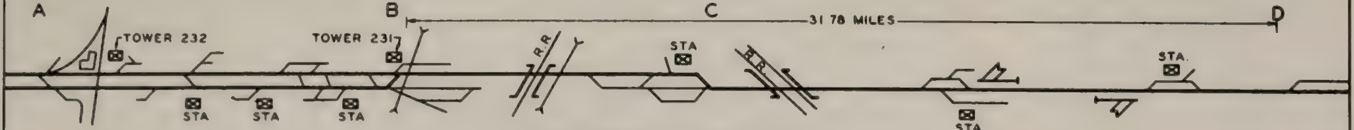

FIG. 2 PRESENT TRACK PLAN

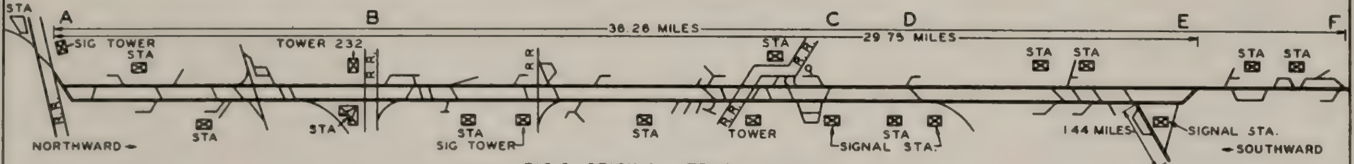

FIG 3 ORIGINAL TRACK PLAN

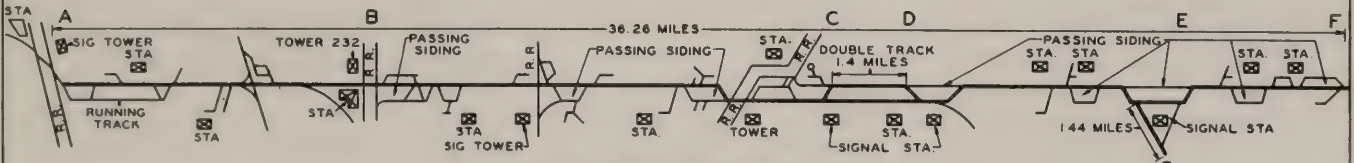

FIG 4 PRESENT TRACK PLAN

EAST AND NORTH RAILROAD

CONVERTING DOUBLE TRACK TO SINGLE TRACK

Conclusions

Where the volume and distribution of traffic on double track has decreased to such an extent that the expense of double-track operation cannot be justified, the economic advantage of converting all or a portion of the double track to single track should be considered. Further, when consideration is given to the progress made in handling increased traffic by modern signal facilities, the economy in maintenance, and the safety of operation, the necessity to return to double track for the efficient operation of trains becomes more remote.

Your Committee recommends that this report be accepted as information.

REPORT OF COMMITTEE XVIII—ELECTRICITY

J. V. B. DUER, *Chairman;*
D. J. BRUMLEY,
J. H. DAVIS,
PAUL LEBENBAUM,
W. L. MORSE,
R. J. NEEDHAM,
E. H. OLSON,
A. E. OWEN,
H. W. PINKERTON,
J. M. TRISSAL,
G. I. WRIGHT, *Vice-Chairman;*
W. M. VANDERSLUIS,
R. P. WINTON,
SIDNEY WITHINGTON,
Committee.

To the American Railway Engineering Association:

Your Committee was instructed to (a) keep the Association informed of developments in the application of electricity to railway service, supplemented with list and reference by number of adopted specifications, design and principles of practice.

SUMMARY OF REPORTS

Power Supply

The collection of pertinent information regarding steam power, water power, and internal combustion plants, with special reference to railway electrification, has been continued.

During the year 1934 no important additions were made to the Central Station capacity of the country, the total additions amounting to only 95,000 KW. Preparations, however, were being made for large additions in 1935 which are estimated to exceed 500,000 KW. The principal steam addition provided for was the 165,000 KW. unit at Richmond Station of the Philadelphia Electric Company. The diesel-electric stationary plants installed in 1934 were confined to small units not normally recorded with the major public utility power plants.

Attention was called to the servicing of equipment along right-of-way for air-conditioning and pre-cooling of cars. The report contains a table giving the characteristics of outside power supply for pre-cooling of air-conditioned cars on various railroads where facilities have been installed and where data has been published.

The report of the United States Geological Survey of April 1935 gives the total power produced for public use in 1934 as 91,150 million kw-hours, 62 per cent of which was produced by thermal plants and 38 per cent by hydro-plants. The equivalent coal consumed in the thermal plants was 41.25 million tons, giving a rate of 1.45 lb. of coal per kw-hour, which is a slight improvement over the 1933 rate of 1.47 lb. per kw-hour and 45 per cent of the 1919 rate.

The Federal Power Commission's "National Power Survey" was continued throughout 1934. This report supplies very complete data on the electric supply industry, together with a most valuable survey of the fuel and water power resources of the country. The report may be of importance to railroads and industries interested in the use of large amounts of electric power. Should rail traffic density be at all favorable in the Tennessee Valley, Boulder Dam, Columbia Valley or Passamaquoddy Districts, the attractive power rates shortly available at these points will very materially enhance the economic possibilities of electric traction. The National Power Survey, according to the interim report, is now studying the possibilities of electrifying certain sections of the following rail systems: Atchison, Topeka and Santa Fe, Boston & Maine, Chesapeake & Ohio, Delaware, Lackawanna & Western, Denver & Salt Lake, New York Central, Norfolk & Western, Pennsylvania, Reading Company, Southern Pacific, and Union Pacific.

Interest continues in the application of diesel power to railroad service. Orders were placed for a large number of 600 HP diesel-electric yard switching locomotives, with indications of a very extended use of this type of motive power. Studies were carried out in the application of diesel-electric locomotives to yard transfer work which resulted in contracts being let for three units with power plants varying from 1800 HP to 2000 HP. Main line locomotive units of 1800 HP were designed, resulting in some preliminary orders being placed early in 1935. These locomotives are now in revenue service. The most spectacular diesel-electric railroad application in this country is prob-

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Bulletin 383, January, 1936.

ably the Burlington Zephyr type trains. The first of these trains, four of which are now in service on the Burlington, went into revenue service on November 11, 1934, and has run in a period slightly over 12 months 187,000 revenue miles.

No new railroad electrification projects were started in 1934. The Pennsylvania continued their electrification program from New York to Washington and actually initiated this electric service on January 28, 1935.

Clearances

The subject of Overhead Clearance Lines for Permanent Way Structures on Electrified Railways received considerable additional study during the year. The replies to a questionnaire sent to thirty-one electrified roads were studied and twenty railroads selected as having typical steam railroad electrifications on which it was thought recommendations should be based. The replies from the twenty railroads were tabulated, corrected by the railroads and included in the report. They constitute an interesting exhibit.

Based on this summary, a series of recommendations for overhead clearance lines for permanent way on electrified railways were prepared and submitted tentatively.

Illumination

Under this heading, the recent developments in incandescent lamps, locomotive and train lighting lamps, and gaseous conductor lamps were reported on in detail.

A comprehensive report is made on car lighting, due to problems arising out of the advent of the high-speed, streamlined trains.

Application of Corrosion-Resisting Materials to Railway Electrical Construction

The samples installed in Hemphill Tunnel on the Norfolk & Western Railway were inspected by members of the Committee in 1935. The samples of Aluminum Strand had become so badly corroded that the wires untwisted and caused a ground, which burned the messenger apart and the samples fell down. The Aluminum trolley clips were badly corroded. All the other samples showed considerable corrosion, but were in a safe condition. The samples in Hemphill Tunnel will be taken down in January, 1936, and weighed. A final report on these samples will be made this year.

Progress reports were also presented on the following subjects:

Electrolysis
Overhead Transmission Line and Catenary Construction
Standardization of Apparatus and Materials
Electric Heating and Welding
Protection of Oil Sidings
Specifications for Track and Third Rail Bonds
Design of Indoor and Outdoor Substations
High Tension Cables
Application of Motors

Bibliography on Application of Electricity to Railways

This valuable bibliography, which includes periodical articles only, is prepared annually, covering the period from July to June. In its preparation the periodicals listed have been examined; these periodicals may be seen in the libraries indicated. The references are arranged in three large groups. Within these, they are arranged under subjects, first, and then in chronological order. An index provides references to the articles by any particular author.

The Committee on Electricity,
J. V. B. Duer, *Chairman.*

REPORT OF COMMITTEE II—BALLAST

A. D. Kennedy, *Chairman;*
A. L. Bartlett,
A. E. Botts,
A. P. Crosley,
J. J. Gallagher,
A. T. Goldbeck,
A. R. Jones,
P. J. McCarthy,
G. J. Nash,
R. H. Pinkham,
J. M. Podmore,
C. P. Richardson,
P. T. Robinson,
W. A. Roderick,
R. L. Sims,
C. B. Stanton,
M. I. Dunn, *Vice-Chairman;*
J. W. Stone,
G. B. Wall, Jr.
Stanton Walker,
C. S. Wicker,
J. B. Wilson,
A. H. Woerner,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith report on its assignment.

(1) Revision of Manual.—Revisions set forth in Appendix A are recommended for adoption.

Appendices A–1, A–2 and A–3 relating to revised Specifications for Stone Ballast are offered as progress and information.

(2) Specifications for Prepared Slag Ballast, Appendix B, are offered for adoption

The Committee on Ballast,
A. D. Kennedy, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

M. I. Dunn, Chairman, Sub-Committee; A. L. Bartlett, A. P. Crosley, A. T. Goldbeck, A. R. Jones, G. J. Nash, R. H. Pinkham, J. M. Podmore, C. P. Richardson, P. T Robinson, R. L. Sims, C. B. Stanton, J. W. Stone, G. B. Wall, Jr., Stanton Walker, A. H. Woerner.

The Committee has reviewed the material now appearing in the Manual, together with authorized revisions, with a view to recommending revisions necessary to eliminate material that is obsolete or not properly within the province of the Ballast Committee, improving the specifications for various types of ballast and revising other material in the interest of completeness and accuracy.

The Committee offers changes in the Manual for reasons given with each paragraph, as follows:

(1) Page 93. "Definition of Spot Board" withdraw, and referred to Committee on "Outline of Work" for reassignment.

(2) Page 93. "Definition of Chert" improve to read: "A compact, flintlike, siliceous rock formed of micro-granular silica of organic or precipitated origin."

(3) Page 93. "Definition of Clay (Burnt) withdraw. (This material no longer in use.)

(4) Page 93. "Definition of Granite (Disintegrated)" improve to read: "Granite which has been subjected to natural weathering conditions to the extent that some of the minerals have been altered, e.g., feldspar to kaolin, mica to chlorite, which alterations are accompanied by considerable loss of mechanical strength in the rock structure."

(5) Page 94. "Definition of Gravel (a), (b) and (c)", improve to read as follows:

Gravel.—The coarse, granular material, larger than sand, resulting from the natural erosion of rock.

Pit-Run Gravel.—The term generally applied to the mixture of gravel, sand and foreign materials as it occurs naturally in any deposit.

Prepared Gravel.—The gravel from which dirt, dust, loam and foreign matter have been removed and which has been prepared to meet specifications (adopted 1930).

Page 94. "Definition of Gumbo" withdrawn. (This material no longer used as ballast.)

Bulletin 384, February, 1936.

(7) Page 94. "Definition of Sand" revised to read—

SAND.—The fine, granular material, usually less than ¼ inch in size, resulting from the natural disintegration of rock or from the crushing of friable sandstone. (For ballast purposes ¼-inch is considered maximum size of sand.)

(8) Page 94: "Definition of Slag"—improve to read as follows: "SLAG.—a nonmetallic fused product resulting from the reduction of ores in furnaces."

(9) "Definition of Slag (Blast Furnace)".—A slag consisting essentially of silicates and alumino—silicates of lime, which is developed simultaneously with iron in blast furnaces (a new definition)

(10) Page 94. "Definition of Stone", improve to read: "CRUSHED STONE.—The product resulting from the artificial crushing of rocks, boulders or large cobblestones, substantially all faces of which have been produced by the crushing operation."

Choice of Ballast (page 94)

Eliminate material under this heading and substitute the following:

"A wide range of materials may be used as ballast and the choice depends on economics and availability. Prepared ballasts are to be preferred, since their production can be controlled and they can be manufactured to conform to specifications.

"Except under special circumstances unprepared ballasts are not recommended for heavy duty track."

Specifications for Prepared Gravel Ballast (Vol. 31, page 768; Bul. 337, p. 7)

A revised specification is now offered which is the result of investigation and research by your Committee. This proposed specification includes improved methods of test and offers grading limits of aggregates that are within the limits of what can be reasonably expected of a well-equipped producer and at the same time a better graduation of ballast. It is recommended that the Specification for Prepared Gravel Ballast referred to be cancelled and the following substituted:

General Characteristics

1. Prepared gravel for ballast shall be composed of hard, strong and durable particles of crushed or uncrushed gravel free from injurious amounts of soft and friable particles and other deleterious substances, and shall conform to the requirements set forth in this specification.

Grading

2. Prepared gravel for ballast shall be graded from fine to coarse within one of the sets of limitations in the following table, depending upon the percentage of crushed particles:

Size of Square Opening Sieve	*Per Cents Passing Each Size*					
	0 to 20% Crushed		*21 to 40% Crushed*		*41 to 100% Crushed*	
	Max.	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*
1½ in.	..	100	..	100	..	100
1 in.	100	80	100	65	95	60
½ in.	80	50	75	35	50	25
No. 4	40	20	35	10	15	0
No. 8	35	15	10	0	5	0
No. 16	25	5	5	0	..	..
No. 50	10	0	..	..	..	..
No. 100	2	0	..	..	..	..

NOTE.—The sieves shall conform to accepted standards for laboratory sieves; sieves of 4 mesh and finer shall conform to the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials; sieves coarser than 4 mesh shall conform to the requirements outlined in Standard Method of Test for Sieve Analysis of Aggregates for Concrete (A.S.T.M. Designation: C 41) of the American Society for Testing Materials, or to requirements subsequently promulgated by either the American Society for Testing Materials or the American Standards Association.

Deleterious Substances

3. Prepared gravel for ballast shall not contain deleterious substances in excess of the following amounts:

Material finer than 200-mesh sieve	1 per cent
Soft and friable particles	5 per cent
Clay lumps	0.5 per cent

Soundness and Resistance to Abrasion

4. (a) Prepared gravel ballast shall be considered to have met the requirements for soundness and resistance to abrasion when satisfactory evidence is available showing that the material has proved satisfactory in service under conditions essentially the same as those for the use for which it is proposed.

(b) Prepared gravel ballast failing to meet the requirements given in Section 4 (a) shall be subjected to the sodium sulfate soundness test and modified Deval abrasion test, and shall meet the following requirements:

Loss in sodium sulfate test, not more than ....———————— per cent[1]
Percentage of wear, not more than:
  Rounded gravel ....———————— per cent[2]
  Crushed gravel ....———————— per cent[2]
  Mixtures of rounded and crushed gravel ....———————— per cent[2]

Test Methods

5. All tests shall be carried out in accordance with the following methods:

(a) *Sampling.* One representative sample shall be taken for each 200 tons of aggregate delivered unless otherwise ordered by the Engineer. Samples shall weigh not less than 50 pounds.

(b) *Sieve Analysis.* The sieve analysis shall be made in accordance with the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (A.S.T.M. Designation: C 41) of the American Society for Testing Materials.

(c) *Material Finer than 200 Mesh Sieve.* The per cent of dust, dirt, loam, and other fine material shall be determined in accordance with the Tentative Method of Test for Determination of Amount of Material Finer Than No. 200 Sieve in Aggregates (A.S.T.M. Designation: C 117–35T) of the American Society for Testing Materials.

(d) *Soft and Friable Particles.* The percentage of soft and friable particles shall be determined in accordance with the Standard Method of Test for Quantity of Soft Pebbles in Gravel (Method T–8) of the American Association of State Highway Officials.

(e) *Clay Lumps.* The percentage of clay lumps shall be determined by examining the various fractions which remain after the sieve analysis. Any particles that can be broken up with the fingers shall be classified as clay lumps and the total percentage of all clay lumps shall be computed on the basis of the total original weight of the sample used in the grading test.

(f) *Soundness.* When the accelerated soundness test is required it shall be made in accordance with the Tentative Method of Test for Soundness of Coarse Aggregate by Use of Sodium Sulfate or Magnesium Sulfate (A.S.T.M. Designation: C 89–35T) of the American Society for Testing Materials or subsequent revisions thereto.

(g) *Percentage of Wear.* When the percentage of wear is required it shall be determined in accordance with the Tentative Method of Test for Abrasion of Gravel (A.S.T.M. Designation: D 289–28T) of the American Society for Testing Materials, except that the sample shall be prepared on the designated sieves with square openings instead of round openings.

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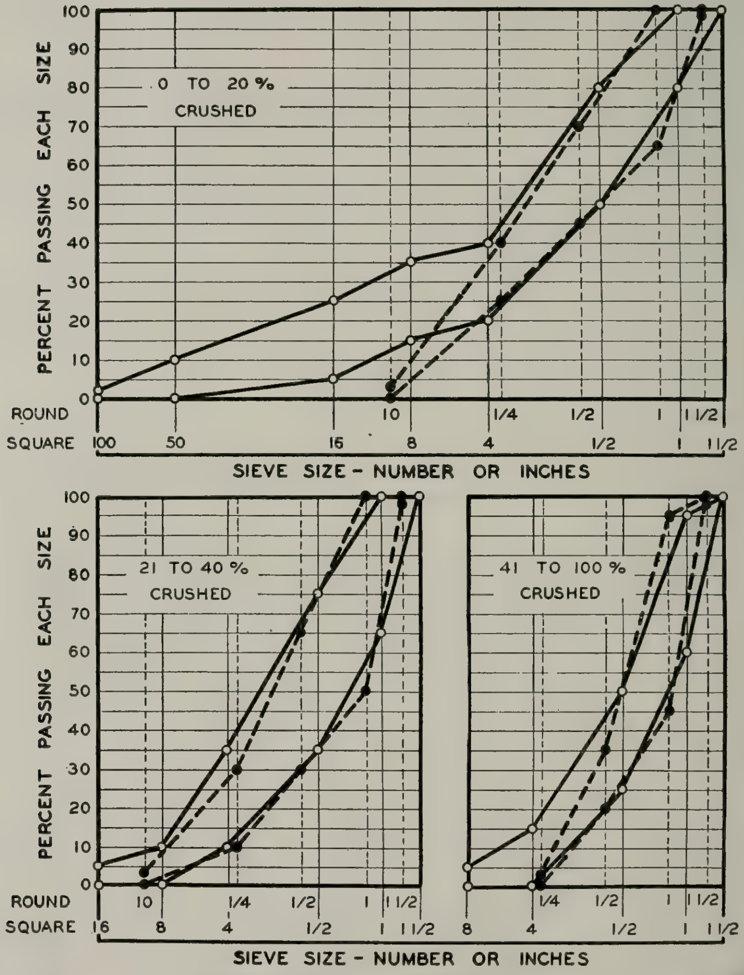
[1] A limit of 15 per cent is commonly specified for concrete aggregates using the present test method; revisions in the test method being discussed will, if adopted, require a modification in specification limits; the Engineer should insert a limit in the specification consistent with local conditions.

[2] Limits frequently specified are 15 per cent for rounded gravel and 25 per cent for gravel consisting entirely of crushed particles; the limiting percentage of wear for mixtures of crushed and uncrushed gravel should be computed as outlined in the test method; the Engineer should insert limits in the specification consistent with local conditions.



COMPARISON OF GRADING LIMITS FOR GRAVEL BALLAST SPECIFICATION

PROPOSED LIMITS —— PRESENT LIMITS - - - -

(h) *Per Cent of Crushed Particles.* The percentage of crushed particles in prepared gravel ballast shall be determined on a representative sample, weighing not less than 10 pounds, of the material coarser than the No. 4 sieve. Particles having one or more faces resulting from fracture shall be considered as crushed particles. The percentage by weight of crushed particles in the material coarser than the No. 4 sieve shall be considered as the percentage of crushed particles in the sample.

Inspection

6. In case inspection and tests show that the material which has been or is being loaded is not in accordance with these specifications, the inspector shall notify the contractor to require that further loading be stopped until the fault has been corrected, and to dispose of all defective material that has been loaded in cars, which shall be done without cost to the railroad.

Measurements

7. (a) When ballast is being paid for by the ton, and it is impracticable to weigh each car, the weight per cubic yard shall be obtained by weighing at frequent intervals not less than five cars loaded with ballast, the contents of which have been carefully measured. The weight per cubic yard obtained by such a test shall be used in figuring the weight per car until another test is made.

(b) When ballast is paid for by the cubic yard, the amount shall be determined by weighing each car, where practicable, and applying the weight per cubic yard as determined by frequent tests. When impracticable to weigh each car, the contents of each car will be carefully estimated by comparison with cars the contents of which have been actually measured.

A graphical comparison of grading limits between the present and proposed specification for Prepared Gravel Ballast is given for information only, and is not intended for printing in the Manual.

Specifications for Pit-Run Gravel Ballast (Pages 100–101)

The removal from the Manual of material on page 22 "Classification of Railways" leaves the material under this heading (Pit-Run Gravel) incomplete.

It is recommended to delete the present specification and substitute the following:

1. Pit-run gravel, to be suitable for ballast, shall meet the requirements for Grade A or Grade B given in these specifications.

2. Pit-run gravel for ballast shall be classified as Grade A or Grade B in accordance with the following limitations.

Sieve Size (Square Openings)	*Amounts Finer Than Each Size Per Cents by Weight*	
	Grade A	*Grade B*
2½ in.	97 to 100	97 to 100
No. 4	20 to 55	20 to 65
No. 200	0 to 2	0 to 3

Methods of Testing Quality of Pit-Run Gravel for Ballast

1. The size of the sample to be tested shall be approximately one cubic foot.

2. Five average samples of about one cubic foot each shall be selected from various parts of the pit which is to be tested. The five samples shall be thoroughly mixed and about one cubic foot of the mixture selected for testing.

3. Sieves used for testing shall comply with Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11–26).

4. The percentage of material finer than the No. 4 sieve shall be determined on a sample weighing not less than 50 lb. which has been dried before test. The result shall be expressed as a percentage by weight of the total sample.

5. The percentage of material finer than the No. 200 sieve shall be determined in accordance with the Tentative Method of Test for Determination of Amount of Material Finer than No. 200 Sieve in Aggregates (A.S.T.M. Designation: C 117–35T).

6. When the sample is shipped for test it shall be carefully and securely marked with the name and location of the pit from which it was taken.

Specifications for Burnt Clay Ballast (Pages 101–102).

Eliminate material under this heading. (This material no longer used for ballast).

Cinder Ballast (Page 102)

Eliminate the last sentence in first paragraph. (Self-evident.)

Proper Depth of Ballast (Page 102)

Withdraw temporarily all material under this heading with the view of giving it further study in collaboration with the proper Committee.

Ballast Sections (Pages 103 to 106 inclusive)

Withdraw temporarily with the view of giving further study in collaboration with the proper Committee.

Organization and Distribution of a Ballast Raising Force of 77 men (Page 107)

Withdraw all information under this heading. (Material obsolete and subject to be referred to proper Committee.)

Organization and Distribution of a small Emergency Ballast Gang (Pages 108–109)

Withdraw all information under this heading. (Material obsolete and subject to be referred to proper Committee.)

Use and Limitation of Mechanical Tools (Page 110)

Delete all information under this heading. (Material obsolete and subject to be referred to proper Committee.)

Use of Mechanical Tampers (Page 110)

Withdraw all information under this heading. (Material obsolete and subject to be referred to proper Committee.)

Rules for Care of Mechanical Tamping Machines (Page 111).

Withdraw all material under this heading. (Material obsolete and subject to be referred to the proper Committee.)

Cleaning Foul Ballast (Page 112)

Delete paragraph (3) and substitute the following: (3) "Clean with ballast forks, screens or other means."

Revise paragraph (9) to read: "After cleaning apply sufficient new ballast to produce the standard section."

Withdraw paragraphs (10), (11) and (12). (Self-evident.)

Reinforcement under Ballast (Page 112)

Delete all information under this heading. Subject to be referred to proper Committee.

Stone and Gravel Ballast Required Per Mile of Track (Page 112)

Withdraw temporarily all information under this heading. (The removal of all material pertaining to Depth of Ballast and Ballast Section renders the information under this heading incomplete.)

Shrinkage Allowance

The information on Ballast Shrinkage given in paragraph (3), page 113, under the heading "Stone and Gravel required per mile of track" should be retained in the Manual under a special heading. The following is recommended:

SHRINKAGE ALLOWANCE

Allowance for shrinkage to be added to measurements in cars at loading point for calculated quantities required is as follows:

Stone Ballast	12 to 15 per cent
Prepared Gravel Ballast	12 to 15 per cent
Blast Furnace Slag Ballast	12 to 15 per cent
Pit-Run Gravel Ballast	8 to 20 per cent

Ballasting by Contract (Page 113)

Withdraw all information under this heading and refer subject to proper Committee. (Self-evident.)

Appendix A–1

SPECIFICATION FOR STONE BALLAST

Your Committee has made a critical study of the "Specifications for Stone Ballast" adopted for inclusion in the Manual in 1931 (see Vol. 32, p. 101), together with subsequent revisions. Special consideration was given to "Gradation in Size," methods of tests and test limits and to the order of presentation.

The specification is submitted at this time for your consideration and your Committee respectfully asks for criticisms and suggestions. In these specifications, the cementing value requirement is omitted and in support of this omission, Appendix A–2, is offered for information only and is not to be included in the Manual. Appendix A–3—"A Report on Specifications Test Limits for Stone Ballast" is offered for information only and is not intended for inclusion in the Manual.

The following specifications, modified if desired, will be presented for adoption in 1937:

SPECIFICATION FOR STONE BALLAST

General Characteristics

1. Crushed stone for ballast shall be composed of angular fragments, reasonably uniform in quality and having the specified durability and wear resisting qualities. It shall be reasonably clean and free from deleterious substances and shall be of the size specified.

Gradation in Size

2. The stone, prepared for use as ballast, shall be well-graded within the size limitations designated in the following table for the size or sizes desired, when tested with square opening laboratory sieves.

Nominal Size Square Openings	*Approximate Size Round Openings*	*Amounts Finer than Each Sieve (Square Opening) Per Cents by Weight*						
		3″	2½″	2″	1½″	1″	¾″	½″
1–2 ″	1¼–2½″	...	100	90–100	35–70	0–15	0–5	....
½–1 ″	⅝–1¼″	...	...	...	100	90–100	....	0–15
¾–1½″	⅞–1¾″	...	...	100	90–100	20–55	0–15	....
¾–2½″	⅞–3 ″	100	90–100	...	25–60	...	0–10	....

Deleterious Substances

3. Broken stone for ballast shall not contain deleterious substances in excess of the following amounts:

Material finer than 200 mesh sieve	1½ per cent
Soft and friable fragments	5 per cent
Clay lumps	0.5 per cent

Physical Requirements

4. (a) Stone ballast shall be considered to have the desired physical requirements when acceptable evidence is available showing that the stone has proved satisfactory in service under conditions essentially the same as those for which it is proposed for use.

(b) Stone ballast failing to meet the requirements in Section 4 (a) shall be subjected to the following physical tests for quality and shall meet the following requirements.

QUALITY REQUIREMENTS

Absorption

5. The absorption shall not exceed .... per cent.

Toughness

6. The toughness shall be not less than ....

Percentage of Wear

7. The percentage of wear shall not exceed .... per cent.

Soundness

8. Stone ballast failing to meet the requirements given in Section 4 (a) shall be subjected to the sodium sulfate soundness test and shall meet the following requirements:

Loss in sodium sulfate test, not more than .... per cent.[1]

Frequency of Testing

9. Tests may be made from time to time at the option of the purchaser, and especially when new strata are being opened up for crushing into ballast.

Selection of Samples

10. Each stratum or portion of the quarry containing a variation in quality of stone, shall be tested separately and not averaged with any other stratum or portion of the quarry.

Averaging of Test Results

11. For obtaining the values of physical tests, the average results of the following number of tests for each sample shall be taken.

Kind of Tests	*Absorption*	*Percentage of Wear*	*Toughness*	*Soundness*
No. of Tests	2	2	(a)	2

(a) Use 6 test cylinders, 3 drilled parallel and 3 at right angles to the bedding plane.

Place of Tests

12. Such tests as are deemed necessary shall be made at a testing laboratory selected by the purchaser, but visual inspection and other tests shall be made at the place of manufacture prior to shipment as often as considered necessary.

PRODUCTION REQUIREMENTS

Handling

13. Broken stone for ballast shall be loaded directly from the screen or from clean bins or from storage piles provided the stone has not become segregated.

Ballast must be loaded into cars which are in good order and tight enough to prevent leakage and waste of material and which are clean and free from sand, dirt, rubbish, or any other substance which would foul or damage the ballast material.

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[1] A limit of 15 per cent is commonly specified for concrete aggregates using the present test method; revisions in the test method being discussed will, if adopted, require a modification in specification limits; the Engineer should insert a limit in the specification consistent with local conditions.

Cleaning

14. When the rock is of such a nature that it does not become clean without preliminary scrubbing, a scrubbing machine shall be provided at the quarry.

Defect Found After Delivery

15. Carloads of defective material arriving at the size for unloading and not previously inspected shall be rejected and be disposed of at the expense of the producer who will be held liable for all freight charges. If unloaded prior to discovery of defectiveness, payment shall be refused to the manufacturer without return of defective ballast.

Inspection

16. Inspectors representing the purchaser shall have free entry to the producing plant at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the producer to satisfy them that the ballast is prepared and loaded in accordance with the specifications and contracts.

In case the inspection develops that the material which has been or is being loaded is not according to specifications, the inspector shall notify the producer to stop further loading and to dispose of all cars under load with defective material.

Measurement

17. Ballast material may be reckoned in cubic yards or by tons, as expedient. Where ballast material is handled in cars, the yardage may be determined by weight, after ascertaining the weight per cubic yard of the particular stone in question by careful measurement and weighing of not less than five cars filled with the material or the tonnage may be determined for subsequent cars by measurement and converting the yardage into tonnage by the use of the weight per yard as determined above.

Methods of Test

18. All tests shall be carried out in accordance with the following methods:

(a) *Sampling the Quarry.* Two samples shall be taken from each ledge or different quality of stone used in the preparation of the ballast.

Samples of the finished product for gradation and other required tests shall be taken from each of 200 tons of aggregate delivered unless otherwise ordered by the Engineer. Samples shall weigh not less than 100 lb.

(b) *Sieve Analysis.* The sieve analysis shall be made in accordance with the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (A.S.T.M. Designation: C. 41) of the American Society for Testing Materials.

(c) *Material Finer Than 200 Mesh Sieve.* The per cent of dust, dirt, loam, and other fine material shall be determined in accordance with the Tentative Method of Test for Determination of Amount of Material Finer than No. 200 Sieve in Aggregates (A.S.T.M. Designation: C 117–35T) of the American Society for Testing Materials.

(d) *Soft and Friable Particles.* The percentage of soft and friable particles shall be determined in accordance with the Standard Method of Test for Quantity of Soft Pebbles in Gravel (Method T–8) of the American Association of State Highway Officials.

(e) *Clay Lumps.* The percentage of clay lumps shall be determined by examining the various fractions which remain after the sieve analysis. Any particles that can be broken up with the fingers shall be classified as clay lumps and the total percentage of all clay lumps shall be computed on the basis of the total original weight of the sample used in the grading test.

(f) *Absorption.* The absorption shall be determined by A.S.T.M. Tentative Standard Test for Absorption by Aggregates for Concrete (A.S.T.M. Designation: C95–33T).

(g) *Toughness.* The toughness test shall be made by A.S.T.M. Standard D 3–18, Test for Toughness of Rock.

(h) *Soundness.* When the accelerated soundness test is required, it shall be made in accordance with the Tentative Method of Test for Soundness of Coarse Aggregate by Use of Sodium Sulfate of Magnesium Sulfate (A.S.T.M. Designation: C89–35T) of the American Society for Testing Materials or subsequent revisions thereto.

(i) *Abrasion Test.* The abrasion test shall be made by A.S.T.M. Standard Method D 2–33.

Appendix A–2

REPORT ON COOPERATIVE TESTS ON THE CEMENTING VALUE OF ROCK FOR RAILROAD BALLAST

PRELIMINARY STATEMENT

A recent questionnaire sent out to the railroads with regard to cementing value of rock ballast showed that of the 58 railroads replying, six railroads have a cementing value requirement in their specifications. Of these six, five specify the A.R.E.A. method of making the cementing value test, while one specifies a modification of this method. The specification requirements vary all the way from 1 pound up to 450 pounds per square inch, indicating that an inconsistency exists, either in the method of making the test or in the test requirements of the rairoad specifying the A.R.E.A. method. Because of this inconsistency it seeemed desirable to initiate a cooperative series of tests to obtain information on this entire matter of the cementing value of rock for use as railroad ballast.

It seemed to your Committee that on rock for railroad ballast investigations were needed involving (1) a determination of the duplicability of the test method when used in different laboratories, (2) a determination of the value of the test method for revealing the cementing value of rock under actual service conditions. Unless the test method will give the same results in different laboratories, the method would seem to be at fault. Accordingly, it was considered by your sub-committee that it would be highly desirable to determine how closely different laboratories check one another on the same samples of rock, making use of the A.R.E.A. test for cementing value.

The following outline of tests was sent to the six railroads requiring the cementing value test in their specification and they were requested to engage in a series of cooperative investigations as hereinafter described.

PROCEDURE TO BE USED IN COOPERATIVE TESTS ON CEMENTING VALUE

For the purpose of investigating the duplicability of the cementing value test in different laboratories it is proposed that each of the cooperating laboratories, preferably including those employed by the six railroads specifying the cementing value test, make tests on six samples of rock in accordance with the following outline.

The same six samples will be used in each laboratory, one sample being collected by each of the cooperating railroads and sent to the other five railroads as well as to the laboratory of the National Crushed Stone Association. An effort will be made to obtain from two of the railroads, samples which have low cementing value; from two others, samples will be required which have acceptable cementing value in service, and from still two others, samples will be requested which have high service cementing value and which give poor results.

METHOD TO BE FOLLOWED IN MAKING THE TESTS

The A.R.E.A. method shall be used in each sample of rock and each sample shall be tested on five different days in order to determine the variation to be expected in the same laboratory. On six samples this will require 30 separate cementing value determinations. For your convenience the A.R.E.A. method of making the cementing determination is as follows:

Cementing Quality

One and one-tenth lb. (½ kg.) of stone which can be crushed to pea size, shall be placed (dry) in a ball mill which contains two steel shot weighing 20 lb. (9.07 kg.) each, given 5000 revolutions at the rate of thirty (30) revolutions per minute, and the dough resulting from a mixture of the dust screened through a 100-mesh sieve, and water placed in an air tight vessel for three (3) hours, and then re-kneaded, shall be made into six cylindrical briquettes 0.98 in. (25 mm.) in diameter and 25 mm. in height formed under a pressure of 1877.5 lb. per sq. in. (132 kg.) after which they shall be allowed to dry 20 hours in air, four hours in a hot air bath at 100° C. (212° F.) and then cooled for twenty minutes in a desiccator, and immediately tested in a machine for ascertaining the crushing strength in pounds per square inch, which is the measure of the cementing value of the rock, the average of five (5) determinations being taken. Rock which has a greater cementing value than .... shall be rejected.

Detailed instructions regarding the collection and shipment of samples will be sent to each cooperating railroad which signifies a willingness to engage in this series of cooperative tests.

RESULTS

Several of the railroads found it impossible to engage in the cooperative series and, finally, three samples were distributed one each by the Boston & Maine Railroad, the Canadian National Railways and the Grand Trunk Western Railroad Company to the following laboratories:

The Canadian Inspection and Testing Co., Ltd.
The Massachusetts Institute of Technology
The National Crushed Stone Association

These laboratories will be referred to as laboratories Nos. 1, 2 and 3.

Results as obtained on these samples by the various laboratories are given in the tables included herewith:

Cooperative Cementing Value Tests on Stone for Railroad Ballast Conducted for the Committee on Ballast, A.R.E.A.

Sample (N.C.S.A. No. 567) Trap Rock from Boston & Maine R. R.

Laboratory No. 1

Run No.	1	2	3	4	5	
Date Tested, 1934	11/9	11/14	11/15	11/16	11/17	
Per cent Water Used	22	22	22	22	22	
Crushing Strength	378	314	345	272	321	
	313	288	323	313	365	
	338	334	321	398	314	
	345	333	318	295	357	Grand Average
	344	326	308	334	316	
Averages	343.6	319	323	322.4	334.6	328.5
Deviation of Daily Average from Grand Average	15.1	9.5	5.5	6.1	6.1	
Per cent from Grand Average	4.6	2.9	1.7	1.9	1.9	

Laboratory No. 2

Run No.	1	2	3	4	5	
Date Tested, 1934	..	..	..	..	..	
Per cent Water Used	..	..	..	..	..	
Crushing Strength	146	106	153	80	146	
	153	146	166	80	139	
	113	106	185	66	132	
	159	113	185	93	106	Grand Average
	139	80	225	73	132	
Averages	142	110	183	78	131	129
Deviation of Daily Average from Grade Average	13	19	54	51	2	
Per cent from Grand Average	10.2	14.8	41.8	39.5	1.6	

Laboratory No. 3

Run No.	1	2	3	4	5	Grand Average
Date Tested, 1934	10/24	10/31	11/7	11/14	11/23	
Per cent Water Used	18	18	18	18	18	
Crushing Strength	445	178	216	548	293	
	445	153	242	560	280	
	458	159	229	560	293	
	472	165	242	585	280	
	445	153	229	548	255	
Averages	452	159	229	560	280	336
Deviation of Daily Average from Grand Average	116	177	107	224	56	
Per cent from Grand Average	34.6	53.5	31.9	66.9	16.2	

(Average Cementing Value (from 3 laboratories) .... 264.5 lbs.
(Deviation from the Average—Laboratory No. 1 .... 64.0 " 24.2%
No. 2 .... 135.5 " 51.2%
No. 3 .... 71.5 " 27.0%

$$\frac{\text{High Ave. (Lab. No. 3)}}{\text{Low Ave. (Lab. No. 2)}} = \frac{336}{129} = 2.60$$

Sample (N.C.S.A. No. 568) Dolomite from Grand Trunk Western R.R. Co.

Laboratory No. 1—No Report

Laboratory No. 2

Run No.	1	2	3	4	5	Grand Average
Date Tested, 1934	..	..	..	..	..	
Per cent Water Used	..	..	..	..	..	
Crushing Strength	139	153	139	126	100	
	132	199	159	106	93	
	146	166	139	100	93	
	126	172	126	113	106	
	119	199	146	106	106	
Averages	132	177	142	110	99	132
Deviation of Daily Average from Grand Average	0	45	10	22	33	
Per cent of Grand Average	0	34.2	7.6	16.7	25.0	

Laboratory No. 3

Run No.	1	2	3	4	5	Grand Average
Date Tested, 1934	10/24	10/31	11/7	11/14	11/23	
Per cent Water Used	18	18	18	18	18	
Crushing Strength	560	765	178	840	166	
	509	803	191	790	153	
	535	733	191	828	166	
	445	713	191	840	153	
	510	612	204	866	166	
Averages	510	726	191	833	161	484
Deviation of Daily Average from Grand Average	26	242	293	349	323	
Per cent of Grand Average	5.4	48.0	60.3	72.0	66.8	

(Average Cementing Value (from 2 Laboratories) .... 308 lbs.
(Deviation from the Average of Laboratory No. 2 .... 176 lb. 57.1%
No. 3 .... 176 lb. 57.1%

$$\frac{\text{(High Average (Lab. No. 3)}}{\text{(Low Average (Lab. No. 2)}} = \frac{484}{132} = 3.67$$

Sample (N.C.S.A. No. 569) Limestone from Canadian National Railways

Laboratory No. 1

Run No.	1	2	3	4	5	6	Grand Average
Date Tested, 1934	11/9	11/14	11/15	11/16	11/17	11/23	
Per cent Water Used	20.6	18	19	19	21/57	20	
Crushing Strength	329	378	394	346	655	417	
	384	372	421	367	616	379	
	404	378	382	347	608	369	
	434	405	388	443	593	339	
	327	357	381	391	590	396	
Averages	378.6	378	393.2	378.8	612.4	380	420
Deviation of Daily Average from Grand Average	44	41.6	26.4	40.8	192.8	39.6	
Per cent of Grand Average	10.5	10.0	5.7	9.8	46.0	9.5	

Laboratory No. 2

Run No.	1	2	3	4	5	Grand Average
Date Tested, 1934	..	..	..	..	..	
Per cent Water Used	..	..	..	..	..	
Crushing Strength	219	178	477	557	384	
	272	166	518	384	239	
	252	292	544	550	404	
	331	404	418	450	464	
	338	331	518	424	285	
Averages	282	274	495	473	355	376
Deviation of Daily Average from Grand Average	94	102	119	97	21	
Per cent of Grand Average	25.1	27.1	34.5	25.8	5.6	

Laboratory No. 3

Run No.	1	2	3	4	5	Grand Average
Date Tested, 1934	11/15	11/19	11/23	11/28	12/16	
Per cent Water Used	18	18	18	18	18	
Crushing Strength	726	803	586	509	573	
	637	867	598	598	700	
	637	854	573	509	650	
	663	828	612	547	675	
	713	789	598	472	612	
Averages	675	828	594	527	643	653
Deviation of Daily Average from Grand Average	22	175	59	126	10	
Per cent of Grand Average	3.3	26.7	9.0	19.2	1.5	

(Average Cementing Value (3 Laboratories) ..... 482.8 lbs.
(Deviation from the Average of Lab. No. 1 ..... 63.2 lbs.—13.2%
Lab. No. 2 ..... 106.8 lbs.—22.2%
Lab. No. 3 ..... 170.2 lbs.—35.2%

$$\frac{\text{High Ave. (Lab. No. 3)}}{\text{Low Ave. (Lab. No. 2)}}=\frac{653}{376}=1.75$$

DISCUSSION OF TEST RESULTS

Considering first the individual test results by a given laboratory on the same sample on the same day, it will be observed that, with some exceptions, they are rather uniform, the greatest deviation occurring in Laboratory No. 2, sample No. 569, second day's run. On the other hand, the average results on the same sample in the same laboratory on different days show a very wide range, a far wider range than is acceptable for acceptance testing. The three laboratories do not agree at all well on results for the same sample as shown by the grand average results given in the following table:

GRAND AVERAGE CEMENTING VALUES

Sample No.	*Type*	*Lab. No. 1*	*Lab. No. 2*	*Lab. No. 3*
567	Trap	328	129	336
568	Dolomite	...	132	484
569	Limestone	420	376	653

In view of the lack of agreement between the several laboratories in results from the same sample, it was determined to obtain from the laboratories, detailed information as to their procedure in conducting the test and a questionnaire was sent to them, the results of which are given in the following table:

Question No. 1. Was any particular gradation used for the stone introduced into the ball mill? If not, what was the approximate size?

Lab. 1. Material all passed No. 4 Tyler sieve, but no dust was used.
Lab. 2. No definite gradation; material crushed so that maximum size was about ⅜ in.
Lab. 3. Approximately ½ to 0.

Question No. 2. What type of ball mill was used for grinding the sample?

Lab. 1. U. S. Standard Ball Grinding Mill, as used for testing road material; two steel shot, ea. 20 lb., speed 2000 r.p.h.
Lab. 2. Type described in U.S. Dept. of Agriculture Bulletin No. 44.
Lab. 3. Olsen machine; essentially the same as described in U.S. Department of Agriculture Bulletin No. 347.

Question No. 3. What was the fineness of the powder resulting from grinding in the ball mill and after screening through the No. 100 sieve?

Lab. 1. No record of sub-sieve sizes. All powder passed through No. 100 screen.
Lab. 2. No way of knowing.
Lab. 3. Unknown.

Question No. 4. How much water was used in preparing the dough for molding the the briquettes?

Lab. 1. Water used included in our report. Trial mixes were carried on different samples in order to produce consistency which would permit of each molding without loss of excess water under pressure. The consistencies for the different samples were as nearly as possible alike.
Lab. 2. As little as possible to give a dough that could be "balled up" in the hands. When more water is used, it is difficult to make the cylinders.
Lab. 3. 90 cc. water to 500 grams of powder.

Question No. 5. How long a time was used in kneading the water with the pulverized rock dust?

Lab. 1. From 3 to 5 minutes.
Lab. 2. About 3 to 5 minutes.
Lab. 3. Approximately 5 minutes before placing in air tight container.. Approximately 5 minutes after three hours in container.

Question No. 6. What type of briquette molding machine was employed?

Lab. 1. Mold as described in U.S. Dept. of Agriculture bulletin, "Physical Testing of Rock for Road Building". Diameter of mold—25 m.m. Capacity 20,000 or 3,000 lb. Total time of compression—20 to 30 sec.
Lab. 2. Mold as described in above bulletin. (U.S.D.A. No. 44). Southwark–Emery hydraulic testing machine for pressure.
Lab. 3. Olsen machine desired for that purpose.

Question No. 7. In drying the briquettes, were they placed on a solid shelf or on a screen?

Lab. 1. Briquettes were placed on a small piece of tin which itself was placed on a screen in the oven.
Lab. 2. On a 4″ by 4″ glass plate on a screen.
Lab. 3. Briquettes were placed on a solid shelf.

Question No. 8. What was the range in temperature of the oven used in drying the samples?

Lab. 1. 212°F. to 213°F. Automatic control.
Lab. 2. 100°C. (1°).
Lab. 3. 180° to 218°F.

Question No. 9. What speed was used in testing the samples? Type of machine?

Lab. 1. (a) Idling speed—0.15 in. per min. Loading speed—500 lb. per min.
(b) Olsen Universal Wire Testing Machine, screw drive, capacity with reducing jockey weight—3000 lb.
Lab. 2. Hydraulic machine was used; probably some variation of speed. Load was self-recording.
Lab. 3. Extremely low rate of application of load at time of failure. Southwark–Emery Hydraulic Machine.

Question No. 10. Was any non-uniformity noticed in the sample at any stage during their preparation or testing?

Lab. 1. Nothing other than one or two samples squeezed out, even with the controlled consistency.
Lab. 2. No marked variation except in fineness of grinding. Some samples pass 100-mesh about 90 per cent, others not more than 60 per cent. These variations noticed in the same stone; sometimes between 2 samples run at the same time in the two parts of mill.
Lab. 3. There was a difference in the consistency and presumably in the gradation.

Question No. 11. Have you any suggestions to offer regarding an improvement in the present test methods?

Lab. 1. In our opinion, the consistency of the dough is apt to cause large variations in results obtained. On the other hand, it would appear to be very difficult to obtain a consistency test that would give the required control of this factor for different types of rock. The rate of loading might also be specified.
Lab. 2. Better gradation of fineness is, I believe, of most importance.
Lab. 3. Make all samples of the same gradation and of uniform consistency. (There is no definite data to substantiate this suggestion.)

There is no outstanding difference in the procedure used that would account for the different results obtained, but obviously there must have been a difference in the methods or in the conditions under which the tests were made which would account for the difference in results obtained. Certainly, the test as described was not adequate since widely different results were obtained in different laboratories and, furthermore, widely different results were obtained in the same laboratory on different days.

Conclusions

1. The A.R.E.A. method for determining cementing value as now described is unreliable as a test method in that:

   (a) Widely different results may be obtained in the same laboratory on the same sample when tested at different times.

   (b) Widely different results may be obtained on the same sample in different laboratories.

2. In view of these wide differences in results, it is now impossible to set a specification limit for cementing value which will differentiate acceptable from unacceptable material.

Appendix A–3

REPORT ON SPECIFICATION TEST LIMITS FOR STONE BALLAST

Your Committee has taken under consideration the matter of proper test limits for absorption, percentage of wear and toughness, for use in the standard Specifications for Stone Ballast. This matter was given careful consideration and your Committee makes the following report:

The Specification for Stone Ballast covers a naturally occurring material whose physical characteristics differ in various parts of the country. A stone which may be considered as relatively poor in one section of the country might be sought after in another where poor material predominates. Considerations of economy prevent the shipment of stone ballast over great distances and accordingly relatively poor material will be used on certain lines merely because it is the best material available in that locality.

The A.R.E.A. specification is a national specification and as such it is intended to serve as a model for the railroads to follow. Obviously, if we set up test limits which give satisfactory results, we must use a test limit which is unnecessarily low for certain railroads (those which can obtain trap rock) and which may be unnecessarily high for other railroads because even the best of their materials does not comply.

In view of the foregoing, it is our opinion that the A.R.E.A. specification will serve the railroads to better purpose if we indicate to them what test values we consider excellent, very good, good or fairly good, and poor. The railroad, in writing its own specification, could then select that set of test values which best suits its local needs.

Only by a comparison of laboratory tests with service behavior can the tests be properly evaluated. So far as we are aware, the only extended coordination of service results on ballast with laboratory tests was made by this Committee in about 1911. A large series of laboratory tests was made by the U.S. Office of Public Roads for the Ballast Committee under the direction of Mr. Goldbeck, and in 1912 F. H. Jackson and A. T. Goldbeck presented a paper before the International Association for Testing Materials. A complete table of the laboratory and service results taken from this paper is to be found on page 111, Vol. 13 of the Proceedings. This information has been averaged for "Excellent", "Very Good", "Good or Fairly Good" and "Poor" results in track and is given in the following table which will serve as a guide to railroad Engineers in designating limits of respective tests called for in the specifications.

AVERAGE RESULTS OF BALLAST TESTS

Results in Track	*Kind of Rock*	*Results in Laboratory*				
		Crushing Strength	*Hardness*	*Toughness*	*Per cent Wear*	*Absorption # per Cu. Ft.*
Excellent	Trap Limestone	(5) 30,450	(6) 17.9	(6) 27	(6) 1.9	(5) 0.39
Very Good	Limestone Sandstone Granite	(4) 27,640	(3) 17.9	(3) 11	(6) 3.4	(3) 0.35
Good or Fairly Good	Limestone Sandstone Granite	(29) 20,510	(31) 14.1	(34) 8	(33) 4.7	(29) 1.03
Poor	Limestone Sandstone Granite	(2) 23,640	(4) 16.9	(3) 6	(4) 4.8	(3) 1.18

Note.—Figures in parentheses indicate number averaged.
Note.—Column on Absorption not in original table.

Appendix B

(2) SPECIFICATION FOR PREPARED BLAST FURNACE SLAG BALLAST

C. S. Wicker, Chairman, Sub-Committee; A. E. Botts, P. J. McCarthy, J. B. Wilson, J. J. Gallagher, W. A. Roderick.

General

Blast Furnace Slag for use in the manufacture of ballast shall be air-cooled and shall consist of angular fragments reasonably uniform in density and quality, and reasonably free from thin, elongated or glassy pieces, dirt or other objectionable matter. Slag shall range with fair uniformity between the maximum and minimum size specified herein.

(II) TESTS

Size

(a) Slag for ballast shall be well graded between the limits specified and shall conform to the following requirements when tested by means of laboratory sieves having square openings.

Nominal Size Square Openings	*Approximate Size Round Openings*	*Amounts Finer than each Sieve (Square Openings) Per Cents by Weight*						
		2½"	2"	1½"	1"	¾"	½"	⅜"
1" to 2"	1¼" to 2½"	100	90–100		0–15	0–5		
½" to 1"	⅝" to 1¼"			100	90–100		0–15	0–5

A sample of not less than 150 pounds shall be used for making the sieve analysis and the percentages passing the designated sieves shall be determined by weight.

Weight

(b) Slag meeting the grading requirements of these specifications shall weigh not less than seventy (70) pounds per cubic foot. The weight determination shall be made according to the standard Method of Test for Unit Weight of Aggregate for Concrete. A.S.T.M. Serial Designation C 29–27.

Soundness

(c) The durability of the material shall be determined by five cycles of the sodium sulphate soundness test. This test shall be made according to the Tentative Method of Test for Soundness of Coarse Aggregates by use of Sodium Sulphate or Magnesium Sulphate (A.S.T.M. C 89–35T). The material shall show not to exceed 15 per cent loss.

Frequency

(d) Tests may be made from time to time at the option of the purchaser.

Selection of Samples

(e) All samples shall be truly representative of the finished product as to quality, size and gradation. Samples of the crushed and screened material shall be selected from the cars, stock pile or bins and be representative of the material to be shipped.

Place of Tests

(f) Such tests as are deemed necessary shall be made at a testing laboratory selected by the purchaser, but visual inspection and other tests shall be made at the place of manufacture prior to shipments as often as considered necessary.

(III) PRODUCTION REQUIREMENTS

Handling

(a) Ballast shall be loaded into cars which are in good order and tight enough to prevent leakage and waste of material and are clean and free from sand, dirt, rubbish, or any other substance which would foul or damage the ballast material.

Cleaning

(b) The ballast shall be free from injurious amounts of dirt, loam, dust or rubbish.

Unit of Quantity

(c) Ballast will be ordered and paid for by the net ton, in carload lots.

Weighing

(d) When it is impracticable to weigh each car, the weight per cubic yard shall be obtained by weighing and measuring at frequent intervals not less than five cars of ballast.

Defect Found After Delivery

(e) As it is impracticable to inspect all the ballast loaded in cars, carloads of defective material arriving at the site for unloading, and not previously inspected, shall be rejected. Upon notification from the purchaser the manufacturer shall immediately arrange for disposition of the rejected material. If unloaded prior to discovery of defectiveness, payment shall be refused to the manufacturer without return of the rejected ballast.

Inspection

(f) Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the ballast is prepared and loaded in accordance with the specifications and contracts.

Your Committee recommends the adoption of these specifications for inclusion in the Manual.

REPORT OF COMMITTEE IX—HIGHWAYS

J. G. Brennan, *Chairman;*
F. D. Batchellor,
H. D. Blake,
F. J. Blickensderfer,
H. E. Brink,
John Carmichael,
H. B. Christianson,
H. M. Church,
S. N. Crowe,
L. B. Curtiss,
A. T. Danver,
C. A. Dayton,
A. R. Dewees,
A. F. Dorley,
G. N. Edmondson,
C. F. Edwards,
P. W. Elmore,
H. L. Engelhardt,
H. W. Fenno,
L. C. Frohman,
P. M. Gault,
R. C. Gowdy,
A. S. Haigh,
J. P. Hallihan,
H. A. Hampton,
W. J. Hedley,
M. V. Holmes,
A. G. Holt,
C. D. Horton,
Maro Johnson,
R. B. Kittredge,
Geo. A. Knapp,
W. B. Knight,
A. E. Korsell,
W. S. Lacher,
Fred Lavis,
E. R. Lewis,
Bernard Blum, *Vice-Chairman;*
E. E. Mayo,
G. P. Palmer,
W. C. Pinschmidt,
T. M. Pittman,
L. J. Riegler,
Frank Ringer,
H. M. Shepard,
F. P. Sisson,
F. C. Squire,
W. C. Swartout,
C. A. Taylor,
A. H. Utter,
V. R. Walling,
R. F. Wood,
Leroy Wyant,
W. L. Young,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual. Progress in study (Appendix A).

(2) Economic aspects of Grade Crossing Protection in lieu of grade separation. Progress in study—no report.

(3) Design and specifications for highway crossings at grade over railway tracks, both steam and electric, collaborating with Committee I—Roadway, and with American Society of Municipal Engineers and American Transit Association. Progress in study—no report.

(4) Comparative merits of various types of grade crossing protection, collaborating with Committee X—Signals and Interlocking, and with Signal Section, Safety Section and Highway Research Board (Appendix B). Progress report.

(5) Difference in costs of highways of various types due to different weights and lengths of trucks (Appendix C). Complete and presented as information.

(6) Automatic pumping stations for use in connection with elimination of grade crossings, collaborating with Committee XIII—Water Service, Fire Protection and Sanitation (Appendix D). Complete and presented as information.

(7) Method of classifying grade crossings with respect to hazard. Progress in study—no report.

Bulletin 384, February, 1936.

Appendix A

(1) REVISION OF MANUAL

HIGHWAY CROSSING SIGNS AND SIGNALS

P. M. Gault, Chairman, Sub-Committee; Bernard Blum, H. D. Blake, H. E. Brink, C. A. Dayton, A. R. Dewees, H. L. Englehardt, H. W. Fenno, A. S. Haigh, M. V. Holmes, Maro Johnson, R. B. Kittredge, E. R. Lewis, G. P. Palmer, W. C. Pinschmidt, L. J. Riegler, Frank Ringer and Leroy Wyant.

Present Form

See Vol. 36, No. 374–Feb., 1935, page 878, Highway Crossing Signs and Signals.

1. Highway Crossing Sign, Fig. 1, to be used as required where manual or automatic protection is not provided.

2. At crossings on heavily traveled highways where conditions justify, either of the following standard visible warning signals should be installed.

(a) Wigwag type, Fig. 2, 3.
(b) Flashing light type, Fig. 4, 5.

3. At crossings where wig-wag or flashing light signals are used, one should be placed on each side of the tracks, Fig. 2, 3, 4, 5.

4. Circuits for automatic operation of wigwag or flashing light signals shall be arranged so that crossing signals will operate until rear of train reaches or clears crossing.

5. Bell should be used on crossing signals only when required by local conditions.

Proposed Form

1. Railroad advance warning signs should be installed and maintained by the highway authorities in accordance with Sections Nos. 145 and 156 of the Manual on Uniform Traffic Control Devices for Streets and Highways of the U.S. Bureau of Public Roads, 1934.

2. Highway crossing signs shall be used as required where manual or automatic protection is not provided:

(a) Fig. 1—painted crossbuck sign.
(b) Fig. 2 and 3—reflector crossing sign assembly may be used with Fig. 1 instead of the painted crossbuck sign, but where automatic signal protection is not required.

3. At crossings on heavily traveled highways where conditions justify, either of the following standard visible warning signals shall be installed:

(a) Wigwag type—Fig. 4 and 5.
(b) Flashing light type—Fig. 6 and 7.

4. At crossings where wigwag or flashing light signals are used, one shall be placed on each side of the track.

5. Same as No. 4, Present form.

6. Bell shall be used on crossing signals when required by local conditions.

7. Aspect.—An electrically or mechanically-operated signal used for the protection of highway traffic at railroad highway grade crossings shall present toward the highway, when indicating the approach of a train, the appearance of a horizontally swinging red light and/or disc.

8. Mounting.—The railroad standard highway crossing sign and the signal shall be mounted on the same post. Either a signal of the flashing light type or one of the wigwag type may be used, but both shall not be placed on the same post.

9. Operating Time.—Automatic signal devices used to indicate the approach of trains shall so indicate for not less than 20 seconds before the arrival of the fastest train operated over the crossing.

Note: Local conditions may require a longer operating time; however, too long an operation by slow trains is undesirable.

Flashing Light Type

10. Height.—The lamps shall preferably be not less than 7 feet nor more than 9 feet above the surface of the highway.

11. Signal lights shall shine in both directions along the highway and shall be mounted horizontally 2 feet 6 inch centers. Lamps when arranged in pairs back to back shall open at the front and be designed so that the door will open to the side or downward.

12. Flashes.—Lights shall flash alternately. The number of flashes of each light per minute shall be 30 minimum, 45 maximum.

13. Hoods and Backgrounds.—Lamp units shall be properly hooded. Backgrounds, 20 inches in diameter, shall be painted black on both sides.

14. Range.—When lamps are operated at normal voltage, the range, on tangent, shall be at least 300 feet on a clear day, with a bright sun at or near the zenith.

15. Spread.—The beam spread shall be not less than 3 degrees each side of the axial beam under normal conditions. This beam spread is interpreted to refer to the point at the angle mentioned where the intensity of the beam is 50 per cent of the axial beam under normal conditions.

16. Lenses or Roundels.—Lenses or roundels shall be 5⅜ inches minimum, 8⅜ inches maximum.

17. Transmission Values (for red lenses and roundels).—Transmission values based on A.A.R. standard scale shall be 150 to 220 where plain cover glass with reflector is used; 220 to 300 where signals are used without reflectors or where a ribbed Spreadlite lens is used in front of the reflector.

18. Short Range Indication.—Signal shall display a satisfactory short range indication.

19. Peep Holes.—Peep holes may be used.

Wigwag Type

20. Length of Stroke.—Length of stroke is the length of chord which subtends the arc, determined by the center of the disc in its extreme positions, and shall be 2 feet 6 inches.

21. Disc.—Size and painting of disc shall be as shown on A.A.R. Signal Section 1553.

22. Number of Cycles.—Movement from one extreme to the other and back constitutes a cycle. The number of cycles per minute shall be 30 minimum, 45 maximum.

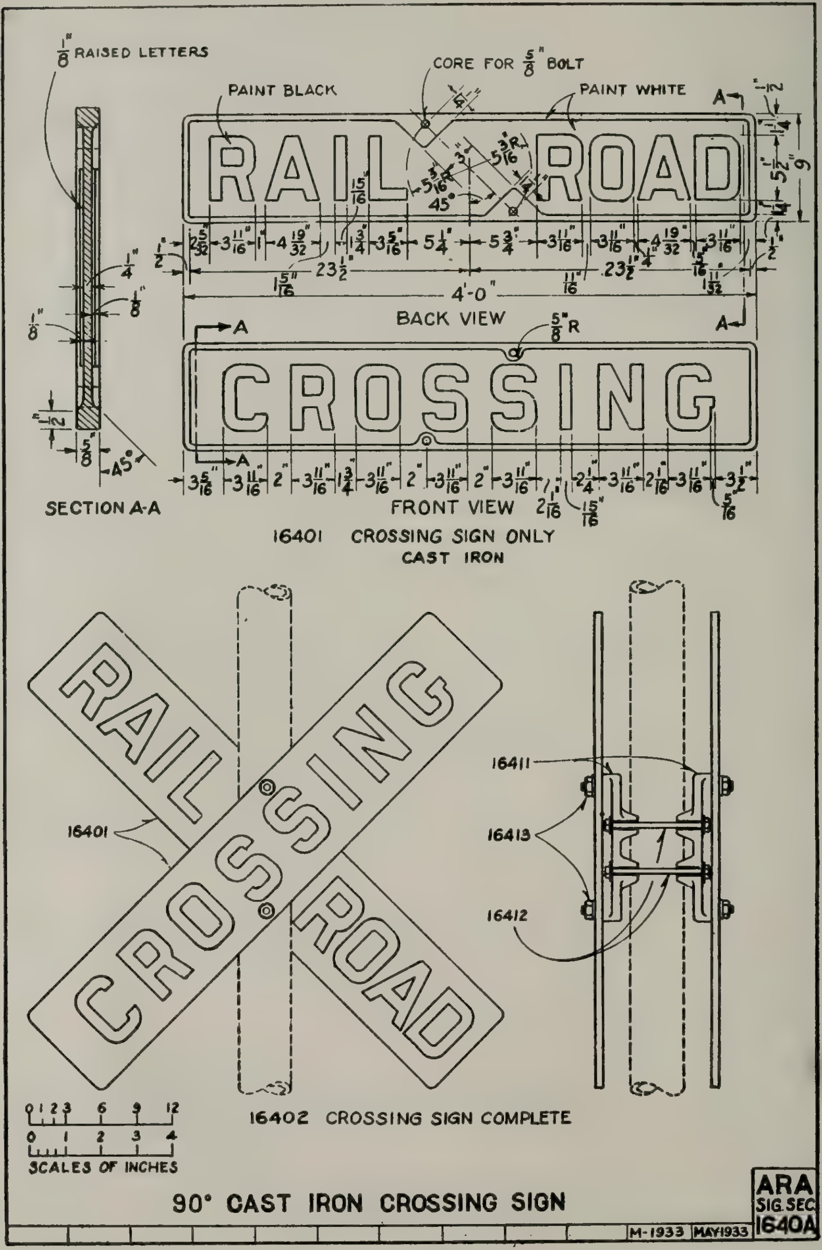

1/8" RAISED LETTERS
PAINT BLACK
CORE FOR 5/8" BOLT
PAINT WHITE
RAIL ROAD
45°
23 1/2"
4'-0"
BACK VIEW
5/8" R
CROSSING
A
A
SECTION A-A
FRONT VIEW
16401 CROSSING SIGN ONLY
CAST IRON
16401
16411
16413
16412
16402 CROSSING SIGN COMPLETE
SCALES OF INCHES
90° CAST IRON CROSSING SIGN
M-1933
MAY 1933
ARA
SIG. SEC.
1640A

Fig. 8.

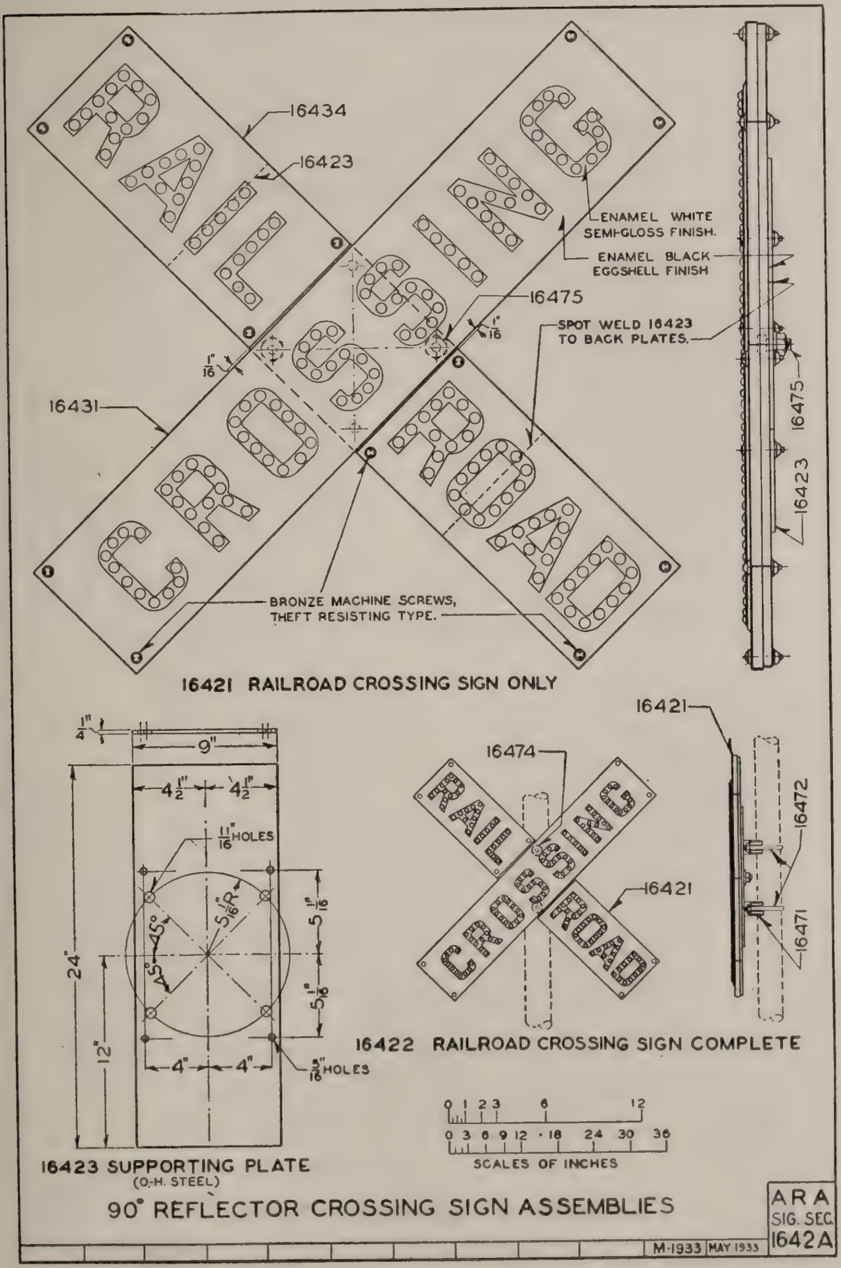

RAIL
CROSSING
ROAD
16434
16423
ENAMEL WHITE SEMI-GLOSS FINISH.
ENAMEL BLACK EGGSHELL FINISH
16475
SPOT WELD 16423 TO BACK PLATES.
$\frac{1}{16}$"
16431
16475
16423
BRONZE MACHINE SCREWS, THEFT RESISTING TYPE.
16421 RAILROAD CROSSING SIGN ONLY
$\frac{1}{4}$"
9"
$4\frac{1}{2}$"
$4\frac{1}{2}$"
$\frac{11}{16}$" HOLES
$5\frac{1}{16}$" R
45°
45°
45°
$5\frac{1}{16}$"
$5\frac{1}{16}$"
24"
12"
4"
4"
$\frac{5}{16}$" HOLES
16423 SUPPORTING PLATE
(O.-H. STEEL)
16421
16474
16472
16421
16471
16422 RAILROAD CROSSING SIGN COMPLETE
0 1 2 3 6 12
0 3 6 9 12 18 24 30 36
SCALES OF INCHES
90° REFLECTOR CROSSING SIGN ASSEMBLIES
ARA
SIG. SEC.
1642A
M-1933
MAY 1933

Fig. 9.

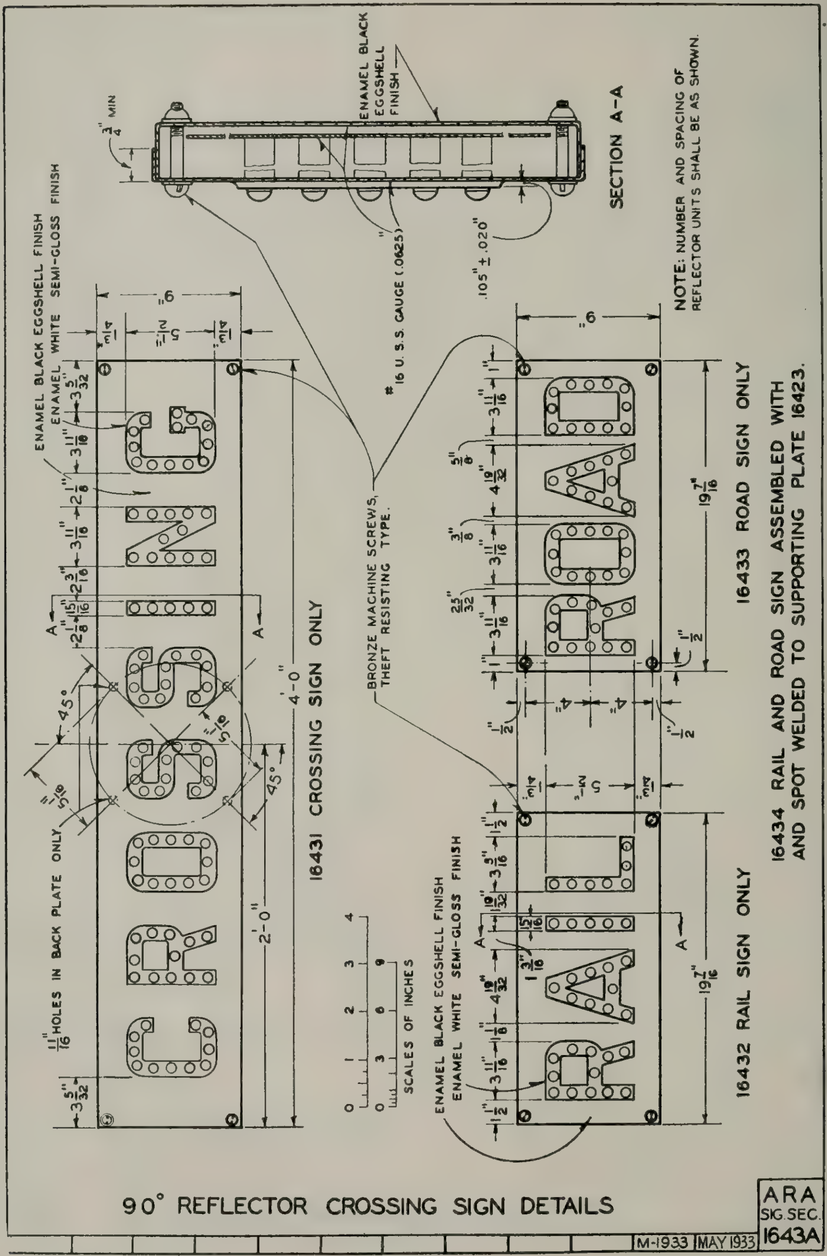

90° REFLECTOR CROSSING SIGN DETAILS
ARA
SIG. SEC.
1643A
M-1933
MAY 1933
16431 CROSSING SIGN ONLY
16432 RAIL SIGN ONLY
16433 ROAD SIGN ONLY
16434 RAIL AND ROAD SIGN ASSEMBLED WITH AND SPOT WELDED TO SUPPORTING PLATE 16423.
SECTION A-A
NOTE: NUMBER AND SPACING OF REFLECTOR UNITS SHALL BE AS SHOWN.
ENAMEL BLACK EGGSHELL FINISH
ENAMEL WHITE SEMI-GLOSS FINISH
11/16" HOLES IN BACK PLATE ONLY
BRONZE MACHINE SCREWS, THEFT RESISTING TYPE.
#16 U.S.S. GAUGE (.0625)
.105" ± .020"
3/4" MIN
SCALES OF INCHES
4'-0"
2'-0"
9"
19 7/16"
45°
A
CROSSING
RAIL
ROAD

Fig. 10.

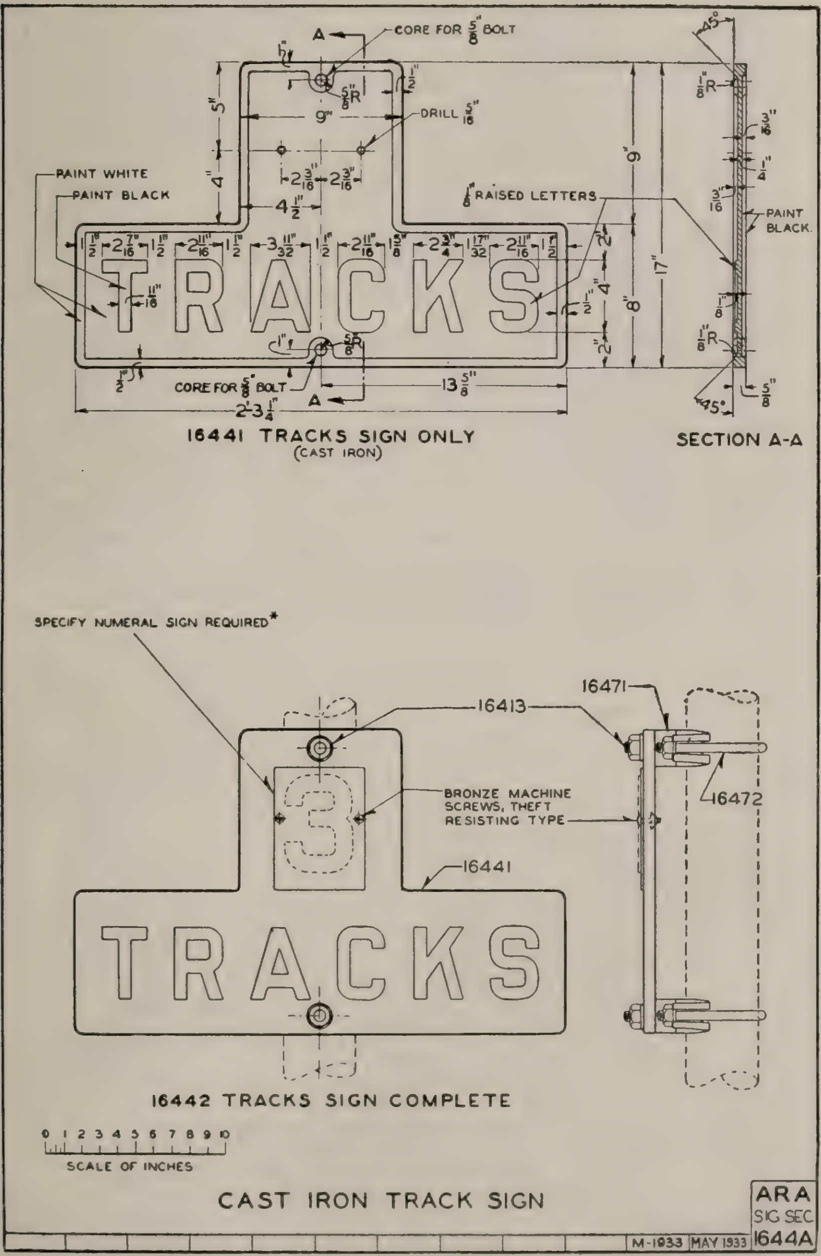

A
CORE FOR 5/8" BOLT
5/8" R
9"
DRILL 5/16"
5"
4"
2 3/16"
2 3/16"
4 1/2"
PAINT WHITE
PAINT BLACK
1/8" RAISED LETTERS
11/16"
1 1/2"
2 7/16"
2 11/16"
3 11/32"
1 5/8"
2 3/4"
1 17/32"
TRACKS
1"
5/8" R
CORE FOR 5/8" BOLT
A
13 5/8"
2'-3 1/4"
9"
17"
8"
2"
4"
1 1/2"
16441 TRACKS SIGN ONLY
(CAST IRON)
45°
1/8" R
3/16"
1/4"
PAINT BLACK.
1/8"
5/8"
SECTION A-A
SPECIFY NUMERAL SIGN REQUIRED*
16413
16471
16472
BRONZE MACHINE SCREWS, THEFT RESISTING TYPE
16441
3
TRACKS
16442 TRACKS SIGN COMPLETE
0 1 2 3 4 5 6 7 8 9 10
SCALE OF INCHES
CAST IRON TRACK SIGN
ARA
SIG SEC
1644A
M-1933
MAY 1933

FIG. 11.

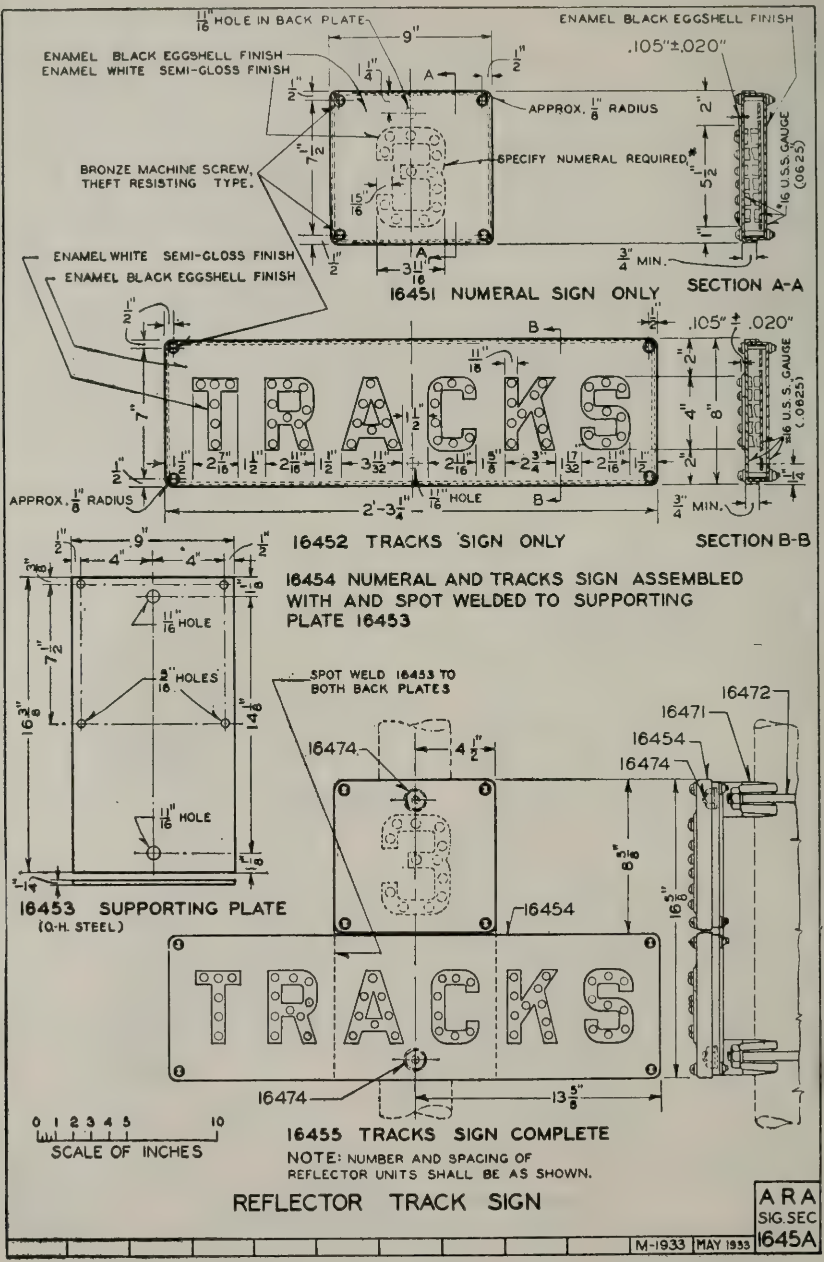
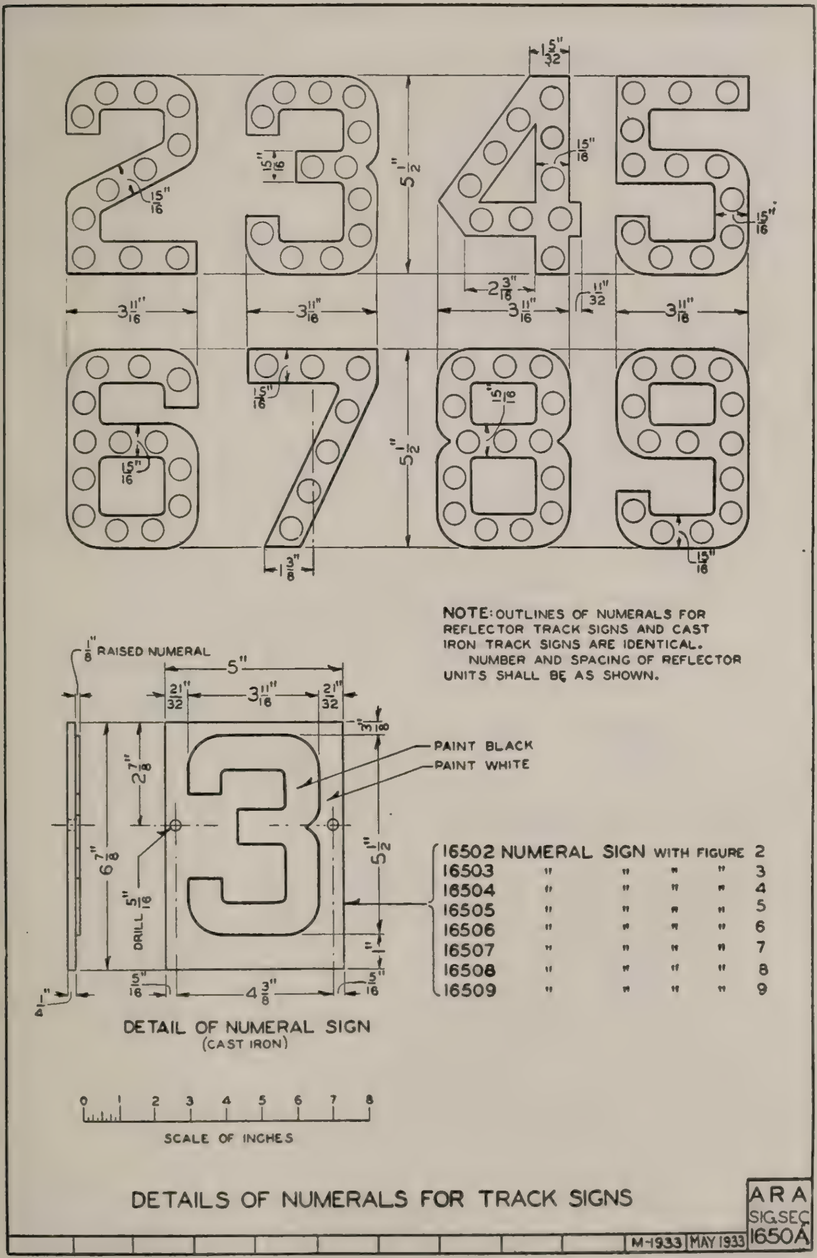

11/16" HOLE IN BACK PLATE
ENAMEL BLACK EGGSHELL FINISH
ENAMEL BLACK EGGSHELL FINISH
ENAMEL WHITE SEMI-GLOSS FINISH
.105"±.020"
APPROX. 1/8" RADIUS
BRONZE MACHINE SCREW, THEFT RESISTING TYPE.
SPECIFY NUMERAL REQUIRED*
16 U.S.S. GAUGE (.0625)
3/4" MIN.
16451 NUMERAL SIGN ONLY
SECTION A-A
ENAMEL WHITE SEMI-GLOSS FINISH
ENAMEL BLACK EGGSHELL FINISH
.105" ± .020"
TRACKS
16 U.S.S. GAUGE (.0625)
APPROX. 1/8" RADIUS
11/16" HOLE
2'-3 1/4"
3/4" MIN.
16452 TRACKS SIGN ONLY
SECTION B-B
16454 NUMERAL AND TRACKS SIGN ASSEMBLED WITH AND SPOT WELDED TO SUPPORTING PLATE 16453
11/16" HOLE
3/16" HOLES
11/16" HOLE
16453 SUPPORTING PLATE
(O-H. STEEL)
SPOT WELD 16453 TO BOTH BACK PLATES
16472
16471
16454
16474
16474
16454
TRACKS
16474
13 5/8"
0 1 2 3 4 5 10
SCALE OF INCHES
16455 TRACKS SIGN COMPLETE
NOTE: NUMBER AND SPACING OF REFLECTOR UNITS SHALL BE AS SHOWN.
REFLECTOR TRACK SIGN
ARA SIG.SEC 1645A
M-1933
MAY 1933

Fig. 12.



NOTE: OUTLINES OF NUMERALS FOR REFLECTOR TRACK SIGNS AND CAST IRON TRACK SIGNS ARE IDENTICAL.
NUMBER AND SPACING OF REFLECTOR UNITS SHALL BE AS SHOWN.

16502	NUMERAL	SIGN	WITH	FIGURE	2
16503	"	"	"	"	3
16504	"	"	"	"	4
16505	"	"	"	"	5
16506	"	"	"	"	6
16507	"	"	"	"	7
16508	"	"	"	"	8
16509	"	"	"	"	9

DETAIL OF NUMERAL SIGN
(CAST IRON)

DETAILS OF NUMERALS FOR TRACK SIGNS

Fig. 13.

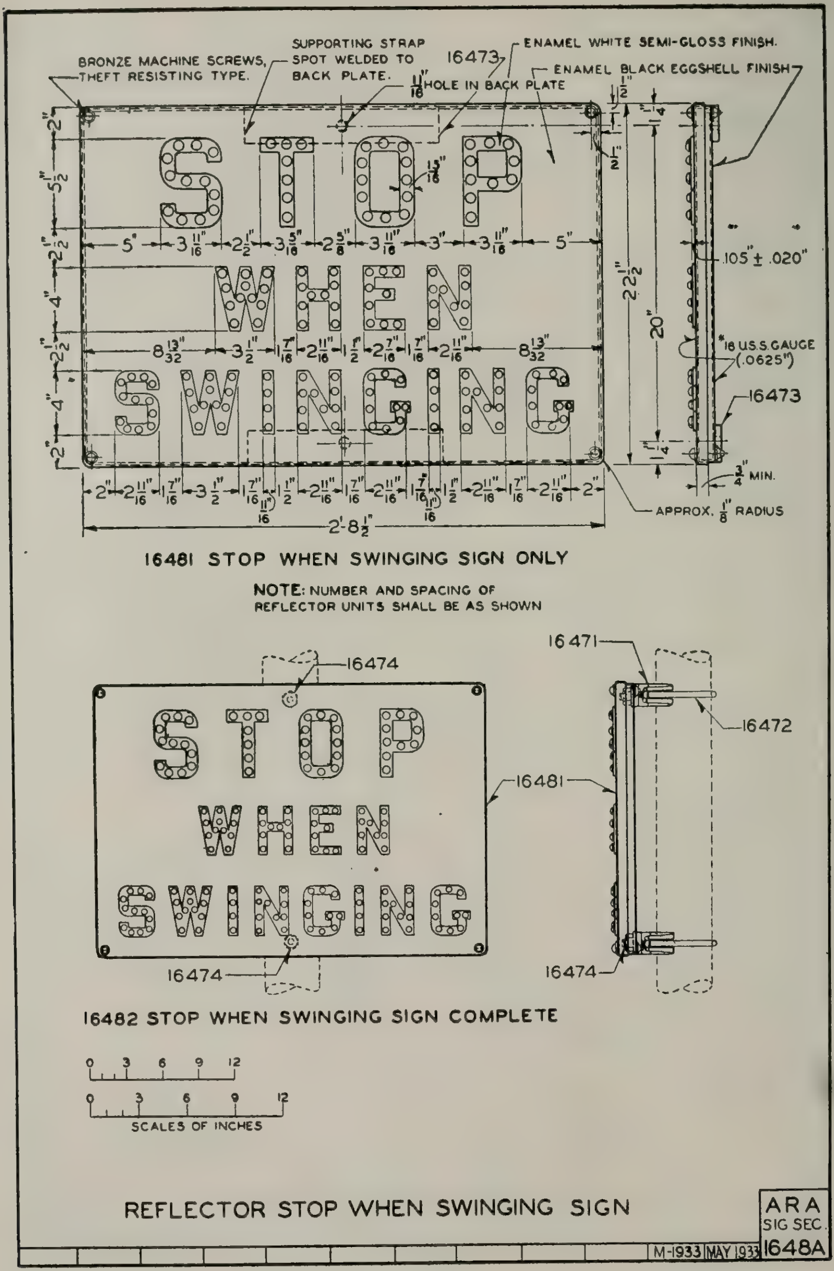

BRONZE MACHINE SCREWS, THEFT RESISTING TYPE.
SUPPORTING STRAP SPOT WELDED TO BACK PLATE.
16473
ENAMEL WHITE SEMI-GLOSS FINISH.
ENAMEL BLACK EGGSHELL FINISH
11/16" HOLE IN BACK PLATE
1/2"
1/4
1/2"
15/16"
STOP
WHEN
SWINGING
2"
5 1/2"
2 1/2"
4"
2 1/2"
4"
2"
5" 3 11/16" 2 1/2" 3 5/16" 2 5/8" 3 11/16" 3" 3 11/16" 5"
8 13/32" 3 1/2" 1 7/16" 2 11/16" 1 1/2" 2 7/16" 1 7/16" 2 11/16" 8 13/32"
2" 2 11/16" 1 7/16" 3 1/2" 1 7/16" 11/16" 1 1/2" 2 11/16" 1 7/16" 2 11/16" 1 7/16" 11/16" 1 1/2" 2 11/16" 1 7/16" 2 11/16" 2"
2'-8 1/2"
22 1/2"
20"
1 1/4
.105" ± .020"
*16 U.S.S. GAUGE (.0625")
16473
3/4" MIN.
APPROX. 1/8" RADIUS
16481 STOP WHEN SWINGING SIGN ONLY
NOTE: NUMBER AND SPACING OF REFLECTOR UNITS SHALL BE AS SHOWN
16474
16471
16472
16481
16474
16474
16482 STOP WHEN SWINGING SIGN COMPLETE
0 3 6 9 12
0 3 6 9 12
SCALES OF INCHES
REFLECTOR STOP WHEN SWINGING SIGN
ARA SIG SEC.
M-1933 MAY 1933
1648A

Fig. 14.

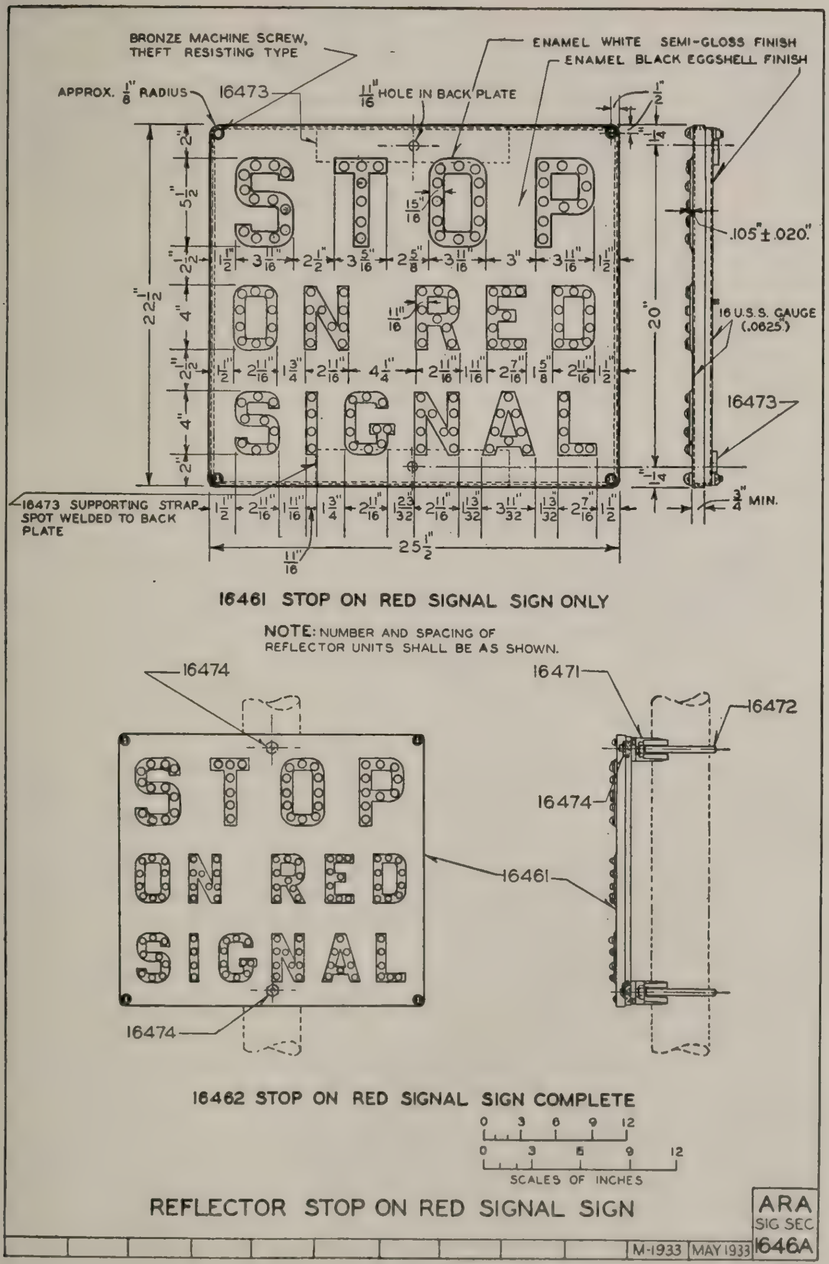

BRONZE MACHINE SCREW, THEFT RESISTING TYPE
APPROX. 1/8" RADIUS
16473
11/16" HOLE IN BACK PLATE
ENAMEL WHITE SEMI-GLOSS FINISH
ENAMEL BLACK EGGSHELL FINISH
1/2
1/4
.105" ± .020"
16 U.S.S. GAUGE (.0625")
16473
20"
1/4
3/4" MIN.
22 1/2"
2"
5 1/2"
2 1/2"
4"
2 1/2"
4"
2"
15/16"
11/16"
1 1/2 3 11/16 2 1/2 3 5/16 2 5/8 3 11/16 3" 3 11/16 1 1/2
1/2 2 11/16 1 3/4 2 11/16 4 1/4 2 11/16 1 11/16 2 7/16 1 5/8 2 11/16 1 1/2
16473 SUPPORTING STRAP SPOT WELDED TO BACK PLATE
1 1/2 2 11/16 1 11/16 1 3/4 2 11/16 1 23/32 2 11/16 1 13/32 3 11/32 1 13/32 2 7/16 1 1/2
25 1/2"
11/16
STOP ON RED SIGNAL
16461 STOP ON RED SIGNAL SIGN ONLY
NOTE: NUMBER AND SPACING OF REFLECTOR UNITS SHALL BE AS SHOWN.
16474
16471
16472
16474
16461
16474
STOP ON RED SIGNAL
16462 STOP ON RED SIGNAL SIGN COMPLETE
0 3 6 9 12
0 3 6 9 12
SCALES OF INCHES
REFLECTOR STOP ON RED SIGNAL SIGN
ARA SIG SEC 1646A
M-1933 MAY 1933

Fig. 15.

Drawings

The drawings in the Manual and Supplements thereto though not in the same order and in some cases not in as complete detail, conform to the drawings shown in the Association of American Railroads Joint Committee on Grade Crossing Protection Bulletin No. 2, Railroad Highway Grade Crossing Protection Recommended Standards.

23. Direction of Lights.—Signal lights shall shine in both directions along the highway.

Drawings

The drawings that follow present the standards recommended for signs and signals to be used for protection at railroad-highway grade crossings. The Specifications shown on figures 8 to 15, inclusive, refer to the Signal Section Manual.

Drawings

Drawing for Highway Crossing signs and signals shall be the same and have the same order and numbering as shown in the Association of American Railroads, Joint Committee on Grade Crossing Protection, Bulletin No. 2, Railroad Highway Grade Crossing Protection Recommended Standards.

Appendix B

(4) COMPARATIVE MERITS OF VARIOUS TYPES OF GRADE CROSSING PROTECTION

H. M. Shepard, Chairman, Sub-Committee; F. D. Batchellor, H. E. Brink, H. B. Christianson, S. N. Crowe, A. T. Danver, A. F. Dorley, L. C. Frohman, P. M. Gault, W. B. Knight, W. C. Pinschmidt, L. J. Riegler, F. P. Sisson, C. A. Taylor, A. H. Utter, V. R. Walling, R. F. Wood and Leroy Wyant.

Following is a list of the various types of grade crossing protection given consideration by the Committee during the past year. They are briefly described from the claims of the manufacturers.

Automatic Crossing Gate.—Manufactured by Automatic Crossing Gates, Inc., Louisville, Ky. This is a hydraulically operated gate controlled electrically by an approaching train. Should a gate descend on a vehicle it is claimed there is no possibility of damage or injury, because of automatic pressure control. The gates are pivotally controlled so as to swing outward to an angle of 120 degrees. This feature makes it possible for a trapped vehicle to go through the closed gates without injury to either gates or vehicles. They work as satisfactorily as any of this general type of automatic power operated gate. At the installations observed flash light signals were used in addition to the gates, although the manufacturer advises some installations of gates have been made without the addition of the flash light signals.

Automatic Safety Gate.—Patentees, Automatic Safety Gate Company, Highland Park, Pa. This is a vertical lift gate, operated by compressed air and controlled electrically by an approaching train. This device is still in the experimental stage and has never been manufactured.

Strauss Yielding Barrier.—Manufactured by Wisconsin Bridge and Iron Company, Detroit, Michigan. This is a vertical gate mounted on steel towers. The barrier net is constructed of two flexible steel cables laced together by rubber belting. The gate is operated electrically by passing of trains. We are advised by the manufacturer of two installations, one that has been in service for more than eight years in the vicinity of Racine, Wisconsin, and the other where Michigan Avenue crosses the river in the city of Buffalo, N. Y. The manufacturer also advises the cost of installing this device at a grade crossing is about $10,000, exclusive of the automatic control features which are estimated to cost about $2,000 more. It is our opinion that this device is in a stage of development and has not been sufficiently perfected for grade crossing use, the cost of construction, operation and maintenance would be considerably in excess of that for present standards of grade crossing protection. The device might be adapted for use in places of special hazard such as drawbridges.

The Committee recommends that the report be received as information.

Appendix C

(5) DIFFERENCE IN COSTS OF HIGHWAYS OF VARIOUS TYPES DUE TO DIFFERENT WEIGHTS AND LENGTHS OF TRUCKS

R. C. Gowdy, Chairman, Sub-Committee; Bernard Blum, H. D. Blake, F. J. Blickensderfer, L. B. Curtiss, A. F. Dorley, C. F. Edwards, H. L. Engelhardt, L. C. Frohman, H. A. Hampton, Maro Johnson, R. B. Kittredge, George A. Knapp, W. S. Lacher, F. Lavis, E. E. Mayo, T. M. Pittman, F. P. Sisson, F. C. Squire, W. C. Swartout, W. L. Young.

It is an elemental principle that the accommodation of heavier and bulkier bodies calls for stronger and larger engineering works. This is supported by the experience of the railroads during the one hundred years of their history. For example, it is virtually axiomatic that wider equipment calls for a corresponding increase in track centers and fixed structure clearances to provide the same degree of safety as that obtained before the wider cars and locomotives were introduced.

It has also been demonstrated by long experience that heavier cars and locomotives demand stronger track and more substantial roadbeds. Failure to provide such heavier construction results in rapid deterioration of the track and/or extraordinary expenditures for upkeep. It is because of these experiences that the railroads generally provide several standards of track construction of different strength and stiffness to meet the varying needs of lines of different volumes of traffic, because heavy locomotives as well as cars of extraordinary loads are intended to run only on tracks of adequate construction.

The Committee is convinced that the same basic principles would apply to the relation between the weights and bulk of highway vehicles and the pavements on which they operate. No facts have been brought forward that afford any valid objection to the conclusion that equal safety of operation calls for equal clearance between vehicles, operating at substantially the same speeds in different lanes, and inasmuch as the large vehicles, especially buses, operate at speeds almost as great as those of the private automobiles, consideration of safety demands a definite relation between the width of the pavement and the width of the vehicles that operate on them.

Insofar as weights of vehicles in their relation to the strength of pavements are concerned, there is ample evidence that heavy loads destroy pavements more rapidly than light ones, but to express this fact in quantitative terms is fraught with marked difficulties. Much has been written on this subject, by men possessed of a broad experience in highway design and construction and who have been able to give their undivided time to a study of the subject. However, regardless of this, there is a total lack of agreement among these authorities. This may be explained in large part by the complexity of the problem, which is comparable with that of determining definitely how much stronger track must be for an E–75 locomotive than for an E–50 engine, something that railway engineers have not completed. It is explained also by the fact that the authors of some of these reports are rather obviously in the position of the advocate of one side of this controversy or the other.

As a consequence, any effort to arrive at reliable conclusions will require the undivided efforts of a staff of qualified engineers who are afforded ample time to assemble, coordinate and weigh all the available data on this subject. It is the opinion of the Committee, also, that such investigations will disclose such a wide variety of conflicting variables that only rather general conclusions will be forthcoming.

Conclusions

The Committee recommends its report be accepted as information and the subject dropped.

Appendix D

(6) AUTOMATIC PUMPING STATIONS FOR USE IN CONNECTION WITH ELIMINATION OF GRADE CROSSINGS

A. R. Dewees, Chairman, Sub-Committee; H. D. Blake, F. J. Blickensderfer, John Carmichael, A. T. Danver, G. N. Edmondson, C. F. Edwards, H. A. Hampton, W. J. Hedley, A. G. Holt, C. D. Horton, A. E. Korsell, E. E. Mayo, W. C. Pinschmidt, T. M. Pittman, H. M. Shepard, W. C. Swartout, V. R. Walling and W. L. Young.

Purpose

Automatic pumping stations should be used in highway underpasses where gravity drainage is not obtainable or where the cost of obtaining gravity drainage is not economically justified.

Determining Factors of Design

In order to determine the proper size of sump and size and type of pumps, it is essential to have complete record of rainfall over an extended period and data on drainage area involved.

Rainfall

If local records are not available, data can be obtained from the Annual Meteorological Summary of the Weather Bureau for the district in which the project is located. Pumping stations designed for a maximum storm occurring in about twenty (20) year cycles are in line with modern sewerage practice.

Drainage Area

The drainage area should be divided into paved area, slope area and outside area. The paved area is the roadway and sidewalks. The slope area is the slopes of the approach cuts entering the subway. The outside area is the area remaining after deducting pavement and slope areas. Provision should be made for future changes that would tend to increase the rate of runoff.

Runoff

The following coefficients of runoff are in general use:

Paved areas—0.85 to 1.00
Slope areas—0.5 to 0.7
Outside areas—0.2 to 0.5

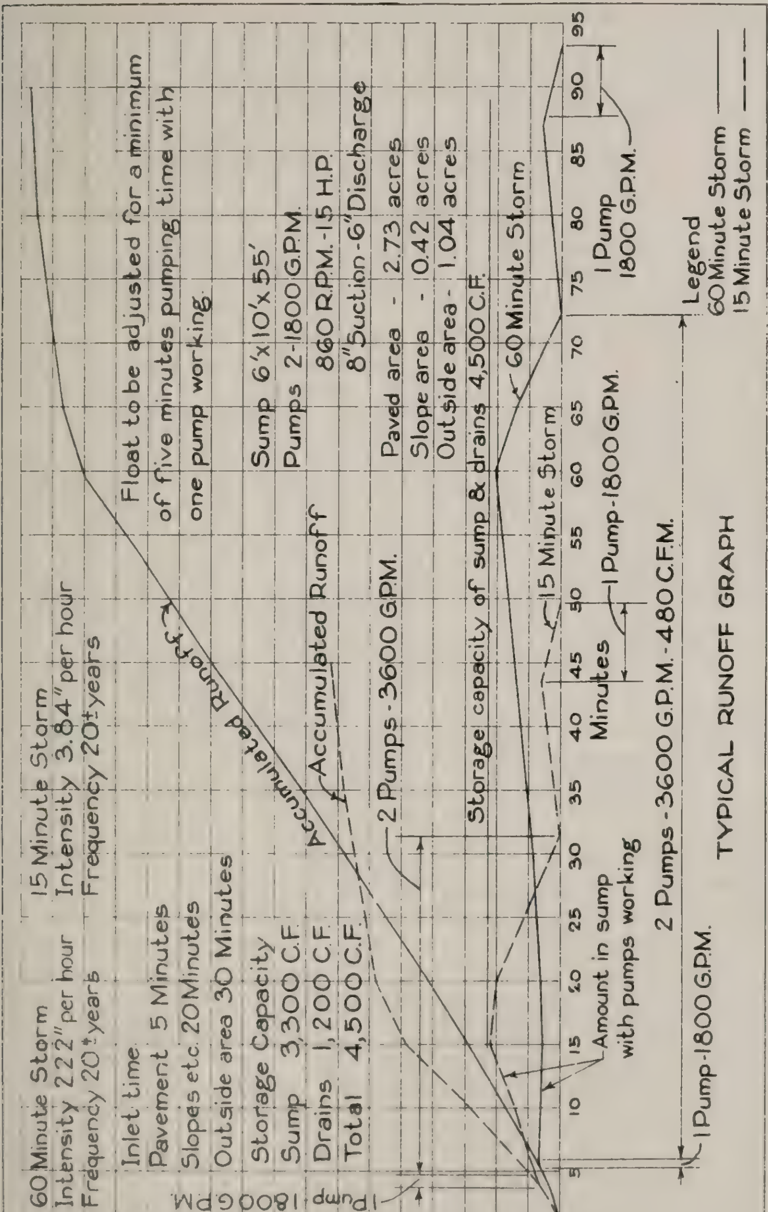
The judgment and experience of the Engineer should govern the factors used.

Inlet Time

It is obvious that the maximum runoff for any given storm will not reach the sump until some time after the storm has started and, of course, it follows that water will continue to enter the sewers after the storm has stopped. An inlet time of five (5) minutes for paved areas, twenty (20) minutes for slopes and thirty (30) minutes for the outside area is conservative for the average underpass.

Method for Determining Capacity of Pumps and Sump

It has been found that a pumping station designed to take care of both the maximum fifteen (15) minute and sixty (60) minute storms will give satisfactory results.



TYPICAL RUNOFF GRAPH

The attached graph indicates the accumulated runoff and the amount of water in the sump for both a typical fifteen (15) minute and sixty (60) minute storm. The most economical size of pump and sump required to fit both storms can be determined approximately by the following formulae in which it is assumed that the first pump will not start until there is enough water in the pump for the pump to run five (5) minutes.

A equals accumulated runoff for sixty (60) minute storm in c.f.
B equals accumulated runoff for fifteen (15) minute storm in c.f.
X equals combined capacity of both pumps in c.f.m.
$A - 55X$ equals $B - 10X$ equals required capacity of sump
$A - B$ equals $45X$
$\frac{A - B}{45}$ equals X

From the attached graph A equals 30,300 c.f.
B equals 9,700 c.f.

X equals $\frac{30{,}300 - 9{,}700}{45}$ equals 457.78 c.f.m. equals required capacity of pumps.

Capacity of Sump for Fifteen (15) and Sixty (60) Minute Storms

$A - 55X$ equals capacity of sump for sixty (60) minute storm
equals $30{,}300 - (457.78 \times 55)$
equals 5,122.1 c.f.

$B - (457.78 \times 10)$ equals capacity of sump for fifteen (15) minute storm
equals $9{,}700 - (457.78 \times 10)$
equals 5,122.2 c.f.

Capacity of sump and drains equals 5,122 c.f.

Two 1800 G.P.M. pumps with total capacity of 3,600 G.P.M. or 480 c.f.m. should be used as the nearest standard size to conform with the required capacity of 458 c.f.m. Using pumps of this size the capacity of the sump is adjusted accordingly.

Type of Pumping Station

Pumping stations are of the dry or wet pit type with dual pumps and motors. There are several kinds of pumping stations, three of which are briefly described as follows:

Tank Stations

This unit is of the dry pit type. The pumps, motors and electrical equipment are housed in a steel tank. The unit is assembled and tested in the factory and is placed entirely underground. Access for inspection and maintenance is provided by means of a manhole located on the top of the tank. The tank is dry and water reaches the pumps by gravity from the sump. Water is pumped to a manhole located nearby and is carried away by a gravity sewer.

Dry Pit and Pumphouse

This type of station is in general use. The pumps, motors and electrical equipment are housed in a waterproof concrete pit with a pumphouse entrance at the street level. Either horizontal or vertical type pumps may be used. If horizontal pumps are used, the pumps and motors are located on the floor of the pit. With a vertical installation the pumps are located on the floor of the pit and connected by shafts to the motors which are usually located above high water level. Water reaches the pumps from the sump by gravity through pipes.

Wet Pit and Pumphouse

This unit consists of a pit with pumphouse entrance at the street level. The pumps are submerged by the water entering the pit from the sump. The motors are located above high water level and are connected to the pumps by shafts inside an outer casing. The pump pit should be divided by a wall and sluice gates provided between the pits and the sump so that a pit may be unwatered and one pump inspected or repaired while the other pump is in operation. Since the pump, shaft and motor are an integral unit, means for installing and removing must be provided in the roof of the pumphouse.

Sump

The sump is often in the form of a reinforced concrete box located under the highway pavement or sidewalk. In some cases it can be located so that curb inlets can empty directly into it. Drain pipes in the subway should be included as a part of the storage capacity.

Pumps and Electrical Equipment

Dual horizontal, or vertical, non-clogging centrifugal sewer pumps may be used. The pumps shall be of proper size to raise the required quantity of water in gallons per minute against the required head and must be able to pass three (3) inch diameter spheres without clogging.

Motors are of the squirrel cage type designed for the required horsepower. Moisture proof motors with automatic magnetic starters are used. Each unit is automatically controlled under pressure with suitable control pressure switch or a float switch.

For pumping stations of the dry-pit type a motor driven fan is required for ventilation. In some locations electrical heating units are required. All electrical connections should be moisture-proofed.

To avoid excessive starting and stopping the first pump should be set so that it will work for at least five (5) minutes. The second pump should be adjusted so that it will cut in at a higher level than the first; this level being reached when the water is entering the sump faster than the first pump can handle it. After the pumps have been started, they continue to work until the water level in the sump reaches its lowest point.

Maintenance and Operation

Pumping plants are usually operated and maintained by the municipality or other authority in which they are located. The demand charge per month is often as much as $1.00 per horsepower. For this reason it is desirable to keep the size of the pump and motor within economical limits.

The report is offered as information.

REPORT OF COMMITTEE XI—RECORDS AND ACCOUNTS

C. C. Haire, *Chairman;*
Anton Anderson,
D. L. Avery,
S. H. Barnhart,
A. M. Blanchard,
E. V. Braden,
E. S. Butler,
P. D. Coons,
W. F. Cummings,
V. H. Doyle,
James Erskine,
P. O. Ferris,
W. E. Gardner,
J. H. Hande,
A. T. Hopkins,
W. W. James,
F. C. Kane,
W. R. Kettenring,
C. A. Knowles,
P. R. Leete,
Henry Lehn,
W. M. Ludolph,
W. S. MacCulloch,
W. S. McFetridge,
E. W. Metcalf,
F. J. Nevins,
A. T. Powell,
H. L. Restall,
B. A. Bertenshaw, *Vice-Chairman;*
F. C. Sharood,
Chas. Silliman,
C. K. Smith,
D. W. Smith,
F. X. Soete,
James Stephenson,
H. J. Stroebel,
D. C. Teal,
A. P. Weymouth,
Louis Wolf,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith reports covering the following subjects:

Group A—Miscellaneous

(1) Revision of Manual (Appendix A).

(2) Bibliography on subjects pertaining to records and accounts (Appendix B). Progress report.

Group B—General Railway Engineering Reports and Records

(1) Office and drafting room practices (Appendix C). Progress report.

Group C—Maintenance of Way Reports and Records

(1) Recommended practice to be followed with respect to maintenance of way accounts and statistical requirements (Appendix D). Progress report.

(2) System of reports and records required to budget and control maintenance of way expenses complete.—Revised report and Exhibits 1, 2 and 3 recommended for Manual.

Group D—Construction Reports and Records

(1) Reports and records (Appendix E). Progress report.

Group E—Property Records and Reports

Methods and forms for gathering data for keeping up-to-date the property records of railways with respect to valuation, accounting, depreciation and other requirements.

(1) Valuation (Appendix F). Progress report.

(2) Accounting and depreciation. Progress in study—No report.

Group F—Accounting Practices Affecting Railway Engineering

(1) Changes or revisions in I.C.C. Classification of Accounts (Appendix G). Progress report.

(2) Methods for avoiding duplication of effort and for simplifying and coordinating work under the requirements of the I.C.C. Progress in study—No report.

The Committee on Records and Accounts,
C. C. Haire, *Chairman.*

Bulletin 384, February, 1936.

Appendix A

(A–1) REVISION OF MANUAL

H. J. Stroebel, Chairman, Sub-Committee; D. L. Avery, S. H. Barnhart, B. A. Bertenshaw, E. S. Butler, P. D. Coons, W. F. Cummings, J. H. Hande, F. C. Kane, W. R. Kettenring, P. R. Leete, Henry Lehn, E. W. Metcalf, A. T. Powell, F. C. Sharood, Chas. Silliman, D. W. Smith, F. X. Soete.

The Committee has made a thorough study of the Manual and Supplements of the chapter on Records and Accounts and, in the light of the proposed general revision in 1936, has, in order to more fully embrace the scope of the section and subject-matter, rearranged the grouping and general headings.

The study has developed the need of dividing the chapter into four major subdivisions, namely:

A General-Records and Reports
B Construction Records
C Maintenance of Way and Structures Records and Reports
D Property Records and Reports

These to be further divided into appropriate subjects coming under each of the above general subjects.

In order to arrange the material in accordance with the above sub-divisions and to bring the Manual up to date, it is necessary to eliminate obsolete matter from the Manual and Supplements, to revise certain existing material and to introduce new matter previously offered as information, and now intended for inclusion in the Manual. The following is a list of such recommended changes:

(1) Definitions.—Delete word "appraised" in definition of "Salvage," and the two definitions for "payroll," on page 81, Bulletin 337, Supplement to the Manual.

(2) Office and Drafting Room Practices. Graphical Symbols.—Volume 36, 1935, pages 391 to 396 inclusive, are recommended for inclusion in the Manual.

(3) Specifications for Preparation of Maps and Profiles.—Volume 36, 1935, pages 384 to 388 inclusive. It is the recommendation of your Committee that these specifications be included in the Manual.

(4) Joint Facility Records.—The Committee has revised the text of the report shown in Volume 34, 1933, page 234, Volume 35, 1934, pages 603 to 609 inclusive, and Volume 36, 1935, pages 398 and 399, in order to condense the material for the Manual. The revised text is shown as Exhibit 1.

It is recommended that the revised text, together with forms and charts shown in the above volumes be adopted for inclusion in the Manual.

(5) Track Chart.—It is the recommendation of your Committee that the insert of the track chart, shown opposite page 740 of the Manual, be deleted, and that the revised chart shown as Exhibit 2 be substituted.

(6) System of Reports and Records Required to Budget and Control Maintenance of Way Expenses.—The text of the report shown in Vol. 36, 1935, pages 400 to 406 inclusive, has been revised in order to condense the material for the Manual. It is recommended that all of the text on page 768 of the Manual and part of that on page 769 to the section headed "Control Through Economy of Maintenance" be deleted and the revised text, together with the forms, Exhibits 1, 2 and 3 shown in Vol. 36, be adopted for inclusion in the Manual. The revision of the text is shown as Exhibit 3.

Exhibit 1

JOINT FACILITY RECORDS

(Sheet 1)

The most commonly used methods of arriving at the rental base or the amount of money upon which the owning road charges a per cent per annum for use of joint facilities are:

(1) Appraised value agreed to by interested parties;
(2) Ledger value or original cost;
(3) Estimated original cost;
(4) Cost of reproduction;
(5) I.C.C. valuation (tentative or final).

The principal modifying factors to be considered in connection with the rental base are:

(1) Age of property;
(2) Condition as regards maintenance and depreciation;
(3) Fluctuating costs affecting value;
(4) Local conditions;
(5) Different capacity requirements of interested parties.

An inventory of the jointly used property should be made as a basis to be used in arriving at the rental base, and after this has been determined it should be kept current by one of the following methods:

(1) Add the net expenditures chargeable to Capital Account, as reflected in the accounting records;
(2) Maintain a detail of the original appraisal with additions and retirements, retiring therefrom items that can be identified or equitably estimated portions thereof at the amount included in such detail for the property retired;
(3) In case of retirements, retire from the rental base the percentage which the property retired bears to the total.

To properly maintain a current rental base the records should show:

(1) That portion of the rental base assignable to each unit of property as of the date of the agreement;
(2) Additions—Amount lodged in the accounting records of the owner and amount added to rental base;
(3) Retirements—Amount retired from books of owner and amount retired from rental base.

Exhibit 1

(Sheet 2)

Form 11..... Rental Base for Joint Facilities. Size 11″ × 17″. For small properties under "Item" list a complete detail of units, but for extensive or complex properties composite items, such as a complete structure, side or yard track, may be used. For recording changes in rental base under the heading "Number Units," each regular horizontal space is divided into two minor horizontal spaces. In the upper of these will be recorded the number of units added, while in the lower will be recorded the number of units retired.

Form 11..... Size, multiple of 11″ × 17″. This is a plan, not drawn to scale, of facilities jointly used, ownership and use being designated by different weights of lines and by symbols. In very complicated layouts colors can be substituted to advantage for different kinds of lines and symbols.

Form 11..... Size, 11″ × 17″. This is a schedule of the joint facilities shown on Form....., and wherever possible, should be placed on Form 11...... It furnishes information as to ownership, maintenance, and operation.

Form 11..... Register of Recurring Accounts. Size, 11″ × 17″. Form is divided into two parts horizontally. The upper part is for recording general information and the lower for recording monthly vouchers and bills. Under column headed "Voucher or Bill No." are two minor horizontal spaces for each regular horizontal space. In the upper is to be entered the voucher or bill number corresponding to the amount in column headed "Maintenance and Operation," while in the lower space will be entered the voucher or bill number corresponding to the amount in the column headed "Rental."

Exhibit 2

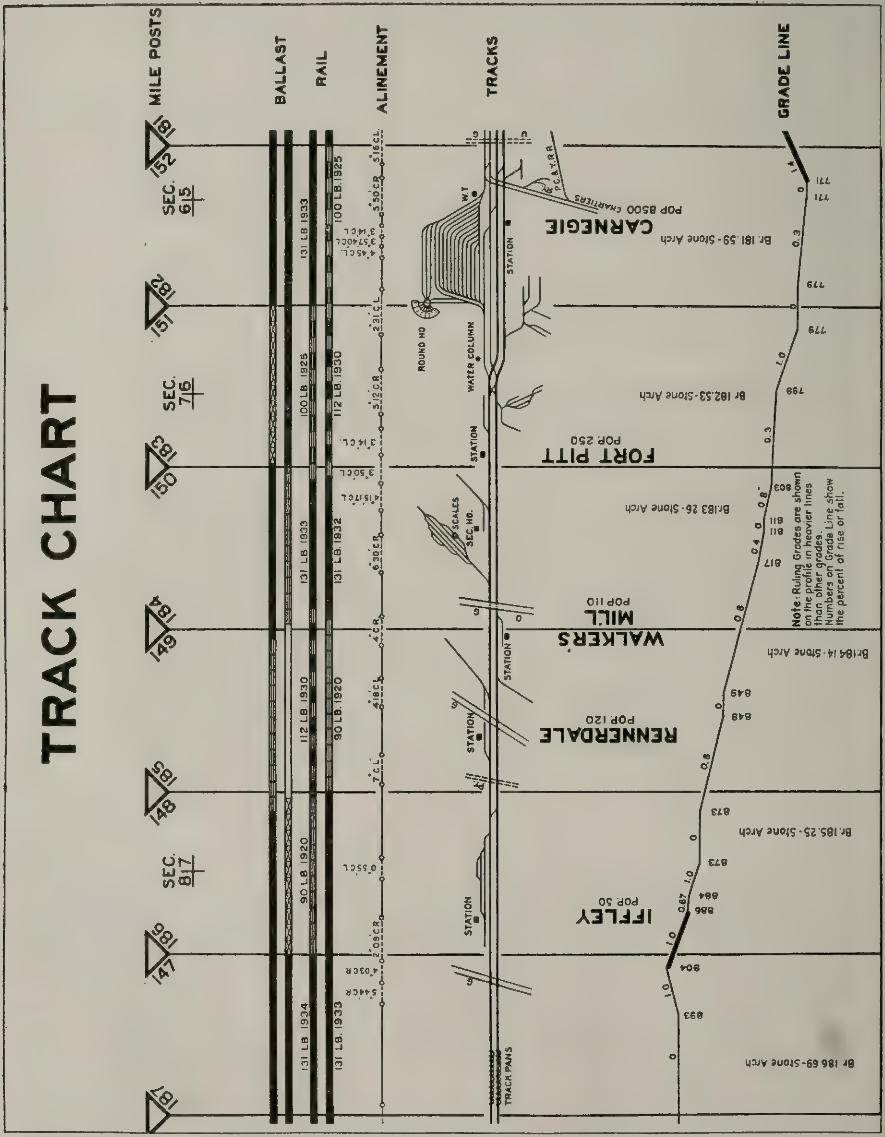

TRACK CHART
MILE POSTS
BALLAST
RAIL
ALINEMENT
TRACKS
GRADE LINE
181 152
182 151
183 150
184 149
185 148
186 147
187
SEC. 6/15
SEC. 7/16
SEC. 8/17
131 LB 1933
100 LB 1925
100 LB 1925
112 LB 1930
131 LB 1933
131 LB 1932
112 LB 1930
90 LB 1920
90 LB 1920
131 LB 1934
131 LB 1933
5°16 C.L.
3°50 C.R.
3°14 C.L.
3°57' 40 C.L.
4°45 C.L.
2°31 C.L.
5°12 C.R.
3°14 C.L.
3°50 C.L.
4°15' 17 C.L.
6°30 C.R.
4° C.R.
4°18 C.L.
7° C.L.
0°55 C.L.
2°09 C.R.
4°03 C.R.
5°44 C.R.
W.T.
STATION
ROUND HO
WATER COLUMN
SCALES
SEC. HO.
TRACK PANS
P.C.&Y.R.R.
CARNEGIE
POP 8500 CHARTIERS
FORT PITT
POP 250
WALKER'S MILL
POP 110
RENNERDALE
POP 120
IFFLEY
POP 50
Br. 181.59 - Stone Arch
Br 182.53 - Stone Arch
Br.183 26 - Stone Arch
Br.184 14 - Stone Arch
Br.185.25 - Stone Arch
Br 186 69 - Stone Arch
771
771
779
779
799
803
811
811
817
849
849
873
873
884
886
904
893
1.4
0
0.3
0
1.0
0.3
0.8
0
0.4
0.8
0
0.8
0
1.0
0.87
1.0
1.0
0
Note: Ruling Grades are shown on the profile in heavier lines than other grades. Numbers on Grade Line show the percent of rise or fall.

Exhibit 3

ESTIMATED EXPENDITURES FOR MAINTENANCE OF WAY AND STRUCTURES FOR CURRENT MONTH OF CURRENT YEAR, COMPARED WITH PREVIOUS MONTH AND SAME MONTH OF PREVIOUS YEAR—(Exhibits 1 and 2, Vol. 36)

The general plan of dealing with expense of the Maintenance of Way and Structures Department is that the Division Engineer after conferring with the Supervisors prepares and submits to the Superintendent on the 15th of the month the above exhibits showing the work it is proposed to undertake during the succeeding month. After being approved by the Superintendent they are furnished in triplicate through the General Superintendent's office to the Engineer Maintenance of Way on the 20th of the month, the General Superintendent summarizing the divisions' requests and adding thereto expenses to be incurred by his office, and those departments not coming under the jurisdiction of the Division Engineer, such as Telegraph and Telephone, and Supervisors of Motor Cars and Work Equipment. The Engineer Maintenance of Way then prepares his recommendations including therein expense to be incurred by his office and submits them to the General Manager on the 24th of the month for authorization.

As soon as the Engineer Maintenance of Way has been advised what he will be permitted to expend in this particular month, a conference is held at the office of the Engineer Maintenance of Way, which meeting is attended by the General Superintendent and District Engineer of the grand district, and all of the Superintendents and Division Engineers within such grand district, at which time a general discussion is conducted in which Division Officers are encouraged to express freely their views and recommendations covering the work at hand. At this meeting the Engineer Maintenance of Way and General Superintendent decide upon the expenses, which, in their judgment, are necessary and advisable. In case all the expenditure requested has not been authorizd, the amount of money to be spent is redistributed between the Bridge, Building, Track, Water Service and other departments where most needed.

The value of these meetings and the discussion of the work are manifold:

> It enables the General Superintendent and District Engineer to obtain information bearing upon the condition on each Division that could not be easily obtained in any other way, and provides for the monthly appropriation to be expended to the best advantage.
>
> It provides a means for a better control of practice on the various Districts and Divisions, and may prevent the use of extravagant methods on lines where the character or quantity of business would not justify as high a class of railroad as on more important lines.
>
> It assists in formulating plans for carrying on the work in a quick and thorough manner, which could not be so well accomplished by correspondence, and minimizes to a very great extent letter writing and the making of reports.
>
> It is of great value to the Division Officers in encouraging them to express their views and opinions about this very important feature of the work. It strengthens them in their responsibility towards the proper maintenance of their territories, makes them feel that their views are worth considering, and brings them in closer contact with the General Officers.

The monthly allotment decided upon is given the Division Officers at this expense conference, and the Superintendent and Division Engineers on reaching their headquarters call a conference of their Supervisors. The expenditures are divided in an equitable manner, each Supervisor being given a definite allowance of men and material covering the monthly period.

The Supervisors in turn advise their respective foremen of their allotment of men and material for the month, and in order to regulate the appropriation, the foremen daily furnish their Supervisors with a statement of the amount of force and material used on the work under their jurisdiction. The Supervisors consolidate these reports and forward them to the Division Engineer, with the result that the Division Officers have immediate knowledge of total expenditures to date.

When extraordinary conditions arise during the month, such as washouts, wrecks, snowstorms, and the like, the practice is to have the Division Superintendents, through their General Superintendent, advise the Engineer Maintenance of Way just how much additional allotment is required. If this extraordinary expense is found extensive, the Engineer Maintenance of Way orders retrenchments on various Divisions of the System in order to offset the extraordinary charges.

COMPARISON OF ACTUAL WITH ESTIMATED MAINTENANCE OF WAY AND STRUCTURES PROGRAM FOR EACH MONTH (Exhibit 3, Vol. 36)

After the accounts are closed for the month, the Division Engineer prepares this exhibit together with a detailed statement of explanations for the increases and decreases, forwarding same to Superintendent. These are then furnished in triplicate through the General Superintendent's office to the Engineer Maintenance of Way, the General Superintendent summarizing the divisions' performances and adding thereto the expenses incurred by his office, and those departments not coming under the jurisdiction of the Division Engineer such as Telegraph and Telephone and Supervisors of Motor Cars and Work Equipment. The Engineer Maintenance of Way summarizes the districts' performances including therein, expenses incurred by his office, and this final report is then submitted to the General Manager.

Appendix B

(A–2) BIBLIOGRAPHY ON SUBJECTS PERTAINING TO RECORDS AND ACCOUNTS

A. P. Weymouth, Chairman, Sub-Committee; E. V. Braden, F. J. Nevins, C. K. Smith, H. J. Stroebel, D. C. Teal.

The method followed in compiling this bibliography for the current year is similar to that of previous years. Each member of the sub-committee was assigned certain periodicals to review and report on important articles, and any new books and documents of outstanding interest to the Association.

The following is submitted as a bibliographical review covering the period from November 1934, to October 1935, inclusive.

BIBLIOGRAPHY

1. Books.

"Railway and Highway Transportation Abroad." A study of existing relationships, recent competitive measures, and coordination policies, by W. Rodney Long, Transportation Division, U.S. Department of Commerce. 426 pages; published by Supt. of Documents, Washington, D. C., March 1935.

"Life Expectancy of Physical Property, based on Mortality Laws" by Edwin B. Kurtz; published by The Ronald Press Co., N. Y. Presents advanced thinking on the problems of depreciation and obsolescence, combining the engineering and accounting aspects involved; illustrated with charts and diagrams.

"Drafting for Engineers"—A textbook of engineering drawing by Carl Lars Svenson, published by D. Van Nostrand Co., New York.

2. Periodicals and Reports of General Interest.

"New Rules for Transportation." Articles in Nation's Business, November 1934, page 30, giving a summary of the transportation and co-ordination situation.

"Over the Hill to Public Ownership." Article in New Outlook, November, 1934, page 32, giving arguments against government ownership.

"Streamlining the Railroads". Literary Digest, June 1, 1935, page 28.

3. Valuation and Accounting.

(a) Legislation and Regulatory Orders.

Motor Carrier Act of 1935—Legislation by Congress to regulate interstate motor vehicle operators.

Interstate Commerce Commission modifies form of Income Statement, effective June 1, 1935, as reported in Railway Age, June 8, 1935, page 895. Also equipment depreciation percentages prescribed by I.C.C. for a list of 75 railroads.

Order of Interstate Commerce Commission, September 16, 1935, relative to Accounting for Ballast, effective January 1, 1936.

(b) Court Decision.

Decision of the U.S. Supreme Court in the Chesapeake and Potomac Telephone case, handed down June 3, 1935, regarding the use of commodity price indices in valuing public utility property. (See abstract in Engineering–News Record for Oct. 10, 1935, p. 496–499).

Appendix C

(B–1) OFFICE AND DRAFTING ROOM PRACTICES

D. L. Avery, Chairman, Sub-Committee; A. M. Blanchard, James Erskine, P. O. Ferris, A. T. Hopkins, C. A. Knowles, W. M. Ludolph, W. S. McFetridge, D. W. Smith, James Stephenson, D. C. Teal, A. P. Weymouth.

The Committee submits herewith progress report consisting of fifteen plates of material. These plates represent such revisions to last year's report as was found necessary because of suggestions and criticisms received; also several new plates have been prepared. The report as submitted covers about fifty per cent of the subjects included under the Committee's assignment.

SIZES OF SHEETS FOR ENGINEERING DRAWINGS, FORMS AND CHARTS

SIZE NO.	SHAPE	A	B	C	D	E	F	G	H	J	TO BE USED FOR	REMARKS All Dimensions In Inches
*1	A	11	8½	1½	¼	2¼	3¼	1			REGULAR DWGS. FORMS AND CHARTS	LENGTHEN BY MULTIPLES OF 7
2	C	11	17		¼						FORMS AND CHARTS	FOR AREA REDUCE 11 HEIGHT TO 7
3	B	11	8½	1½	¼	2¼	3¼	1			REGULAR DWGS. R. OF W. AND CONTRACT	TITLE MAY BE CHANGED AS INDICATED
4	A	10½	8	1½	¼						I.C.C. APPLICATION MAP	NO TITLE BLOCK
5	A	21	16	1½	½						DO	DO
*6	D	17	22	1½	½	3	4½	1¼			REGULAR DRAWINGS	LENGTHEN BY MULTIPLES OF 14
*7	D	22	34	1½	½	3	4½	1¼			DO	DO
*8	D	34	44	1½	½	3	4½	1¼			DO	DO
9	C	24	56		½	6	9				I.C.C. RIGHT OF WAY MAPS	
10	A	7	4		½						CUTS FOR AREA REPORTS	REDUCTION OF SIZES-11-12
11	A	14	8		½						DETAIL DWGS. FOR AREA BULLETINS	WORKING SIZE
12	A	21	12		½						DO	DO
13	D	9	12½	1½	½						AREA TRACKWORK PLANS	LITHOGRAPHIC SIZE
14	D	18	25	3	1						DO	WORKING SIZE. INCREASE B TO SUIT
15	D	8½	17	1½	½	2½	3½	1¼			FOR STANDARD DWGS. ONLY	LITHOGRAPHIC SIZE
16	D	17	34	3	1	5	7	2½			DO	FOR DETAILING. INCREASE B TO SUIT
*17	D	11	17	1½	½	3	4½	1¼			REGULAR DRAWINGS	
18												

*AGREES WITH A.S.A. Z-14.1-1935

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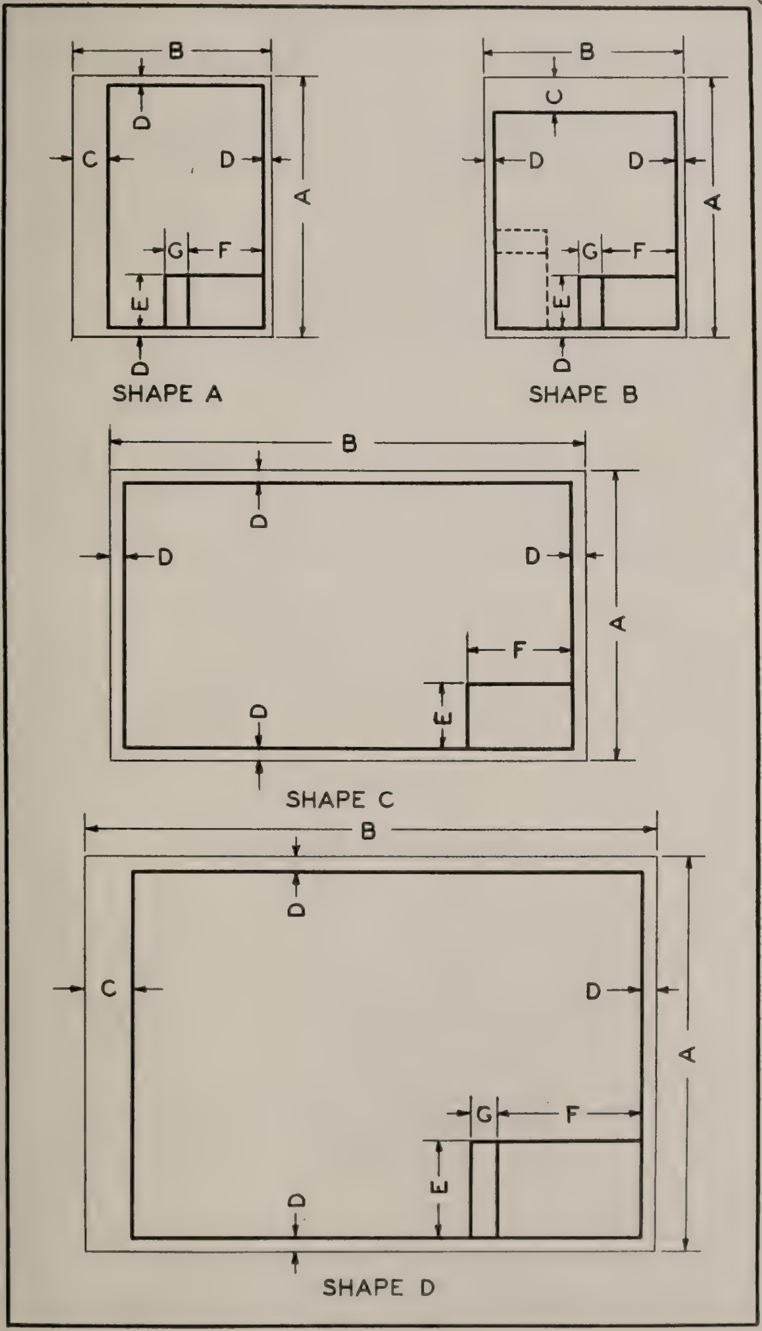
B
D
C
D
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SHAPE A
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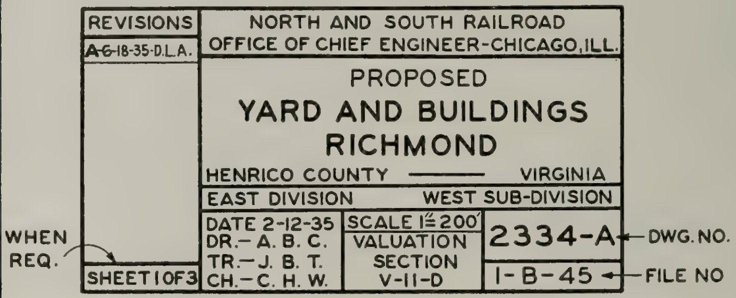
SHAPE D

③

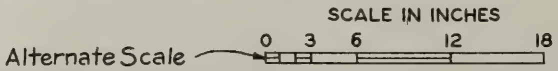
TYPICAL TITLES

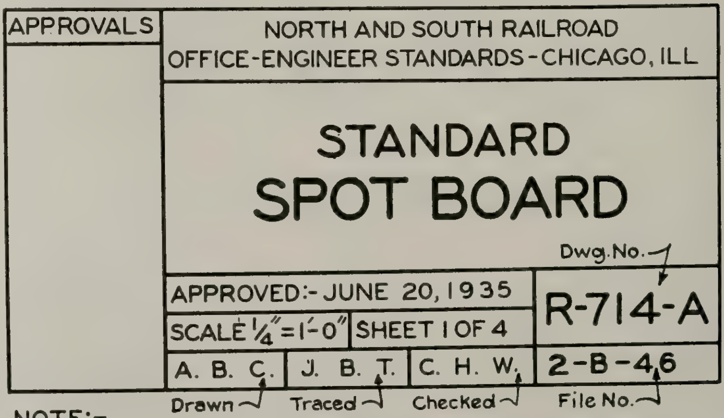
SCHEME "A"



NOTE:—

TITLE FOR OTHER THAN STANDARD DRAWINGS. THE INFORMATION WHICH IS NEEDED IN A TITLE WILL VARY WITH OFFICE PRACTICE. TYPE AND USE OF DRAWING. ONE (1) REFERS TO FILE CASE; B REFERS TO DRAWER OR COMPARTMENT; FOURTY FIVE (45) REFERS TO POSITION IN DRAWER OR COMPARTMENT





NOTE:—

TITLE FOR STANDARD DRAWINGS. VARIATIONS IN ORGANIZATIONS AND OFFICE PRACTICE WILL DETERMINE THE INFORMATION WHICH IS NEEDED.

THE FOLLOWING LETTERS WILL BE USED AS ABBREVIATIONS FOR CLASSES OF DRAWINGS.

A-BUILDINGS	B-BRIDGE	E-ELECTRICAL
R-ROADWAY	S-SIGNAL	T-TRACK
W-WATER SUPPLY		

THE "A" IN DRAWING NUMBER DESIGNATES FIRST REVISION; "B" SECOND REVISION, ETC.

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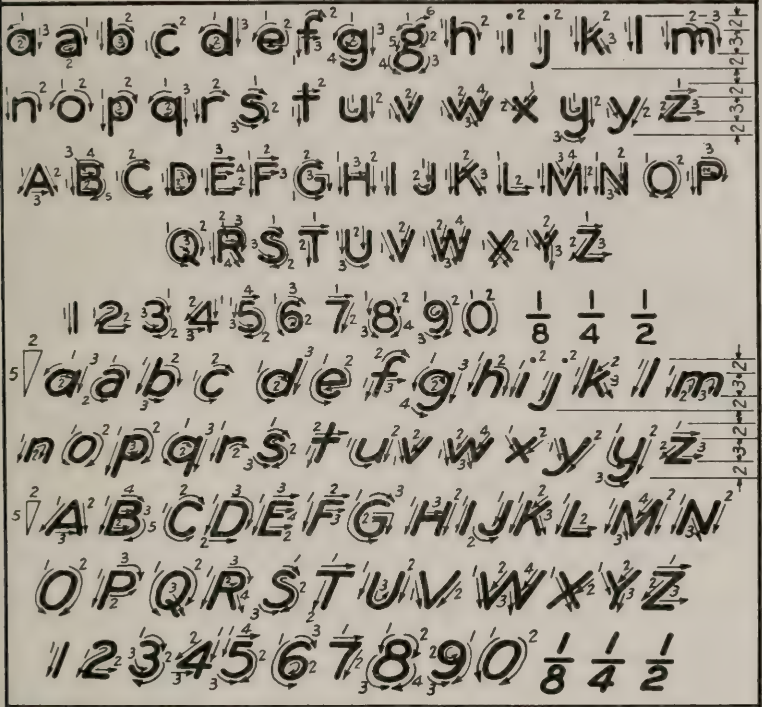
LETTERING



TYPE	
1	TITLES & DRAWING NUMBERS
2	FOR SUB-TITLES OR MAIN TITLES ON SMALL DRAWINGS
3	FOR HEADINGS AND PROMINENT NOTES
4	FOR BILLS OF MATERIAL, DIMENSIONS & GENERAL NOTES
5	OPTIONAL TYPE SAME AS TYPE 4 BUT USING TYPE 3 FOR FIRST LETTERS OF PRINCIPAL WORDS. MAY BE USED FOR SUB-TITLES AND NOTES ON THE BODY OF DRAWINGS.
6	Plate "A" Profile Paper — Type 6 may be used in place of Type 4 with capitals of Type 3 for Bills of Material and Notes on Body of Drawing. $\frac{3}{20}''$ $\frac{2}{20}''$

TYPE	
/	***TITLES & DRAWING NUMBERS***
2	***FOR SUB-TITLES OR MAIN TITLES ON SMALL DRAWINGS***

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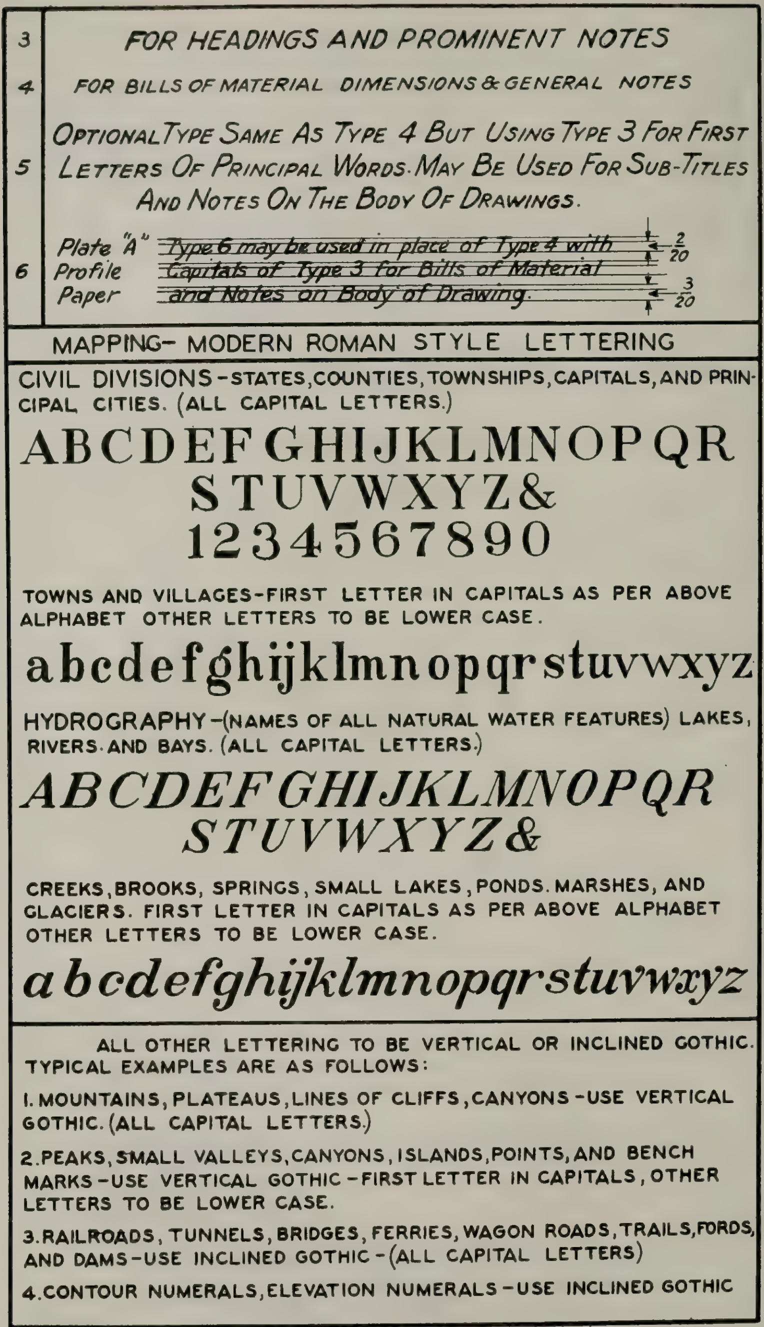

3 FOR HEADINGS AND PROMINENT NOTES

4 FOR BILLS OF MATERIAL DIMENSIONS & GENERAL NOTES

5 Optional Type Same As Type 4 But Using Type 3 For First Letters Of Principal Words. May Be Used For Sub-Titles And Notes On The Body Of Drawings.

6 Plate "A" Profile Paper — Type 6 may be used in place of Type 4 with Capitals of Type 3 for Bills of Material and Notes on Body of Drawing.

MAPPING— MODERN ROMAN STYLE LETTERING

CIVIL DIVISIONS—STATES, COUNTIES, TOWNSHIPS, CAPITALS, AND PRINCIPAL CITIES. (ALL CAPITAL LETTERS.)

ABCDEFGHIJKLMNOPQR
STUVWXYZ&
1234567890

TOWNS AND VILLAGES—FIRST LETTER IN CAPITALS AS PER ABOVE ALPHABET OTHER LETTERS TO BE LOWER CASE.

abcdefghijklmnopqrstuvwxyz

HYDROGRAPHY—(NAMES OF ALL NATURAL WATER FEATURES) LAKES, RIVERS AND BAYS. (ALL CAPITAL LETTERS.)

ABCDEFGHIJKLMNOPQR
STUVWXYZ&

CREEKS, BROOKS, SPRINGS, SMALL LAKES, PONDS. MARSHES, AND GLACIERS. FIRST LETTER IN CAPITALS AS PER ABOVE ALPHABET OTHER LETTERS TO BE LOWER CASE.

abcdefghijklmnopqrstuvwxyz

ALL OTHER LETTERING TO BE VERTICAL OR INCLINED GOTHIC. TYPICAL EXAMPLES ARE AS FOLLOWS:

1. MOUNTAINS, PLATEAUS, LINES OF CLIFFS, CANYONS—USE VERTICAL GOTHIC. (ALL CAPITAL LETTERS.)
2. PEAKS, SMALL VALLEYS, CANYONS, ISLANDS, POINTS, AND BENCH MARKS—USE VERTICAL GOTHIC—FIRST LETTER IN CAPITALS, OTHER LETTERS TO BE LOWER CASE.
3. RAILROADS, TUNNELS, BRIDGES, FERRIES, WAGON ROADS, TRAILS, FORDS, AND DAMS—USE INCLINED GOTHIC—(ALL CAPITAL LETTERS)
4. CONTOUR NUMERALS, ELEVATION NUMERALS—USE INCLINED GOTHIC

AGREES WITH A.S.A. Z-14.1-1935

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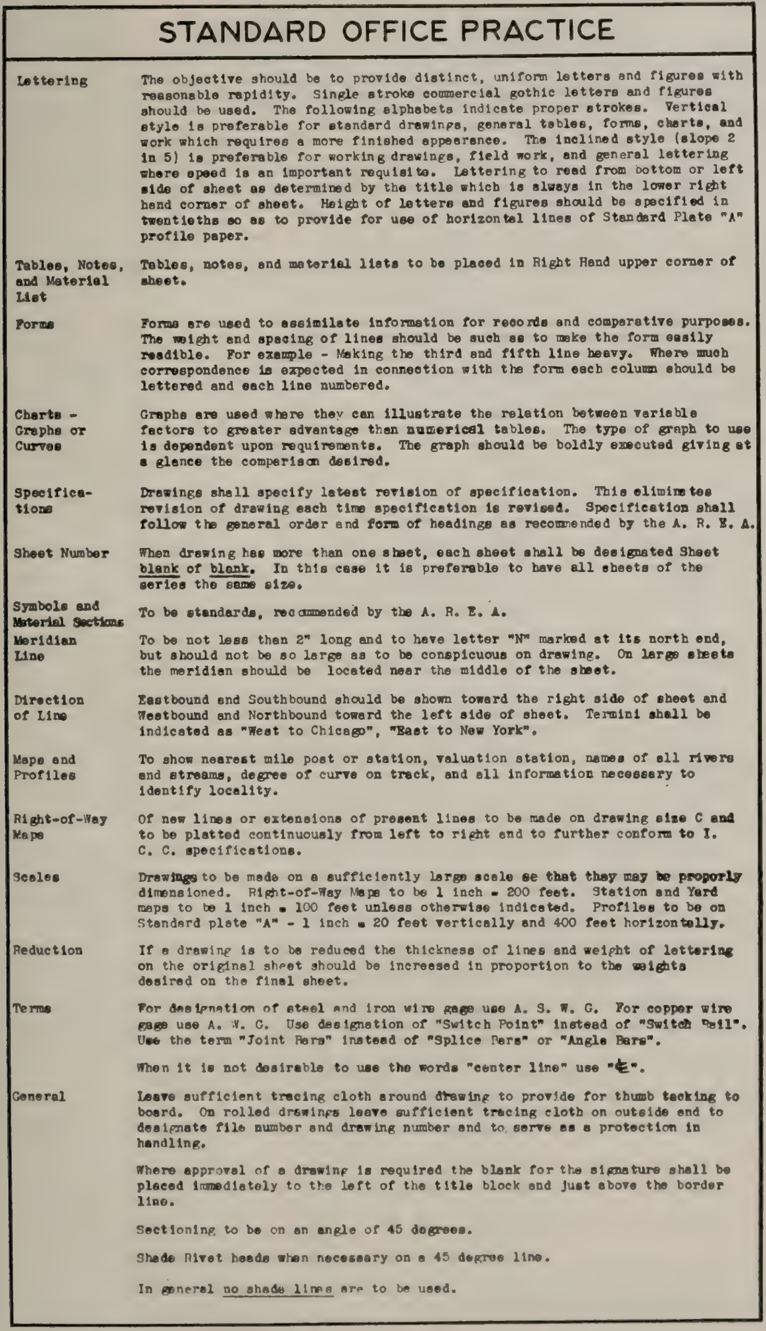

STANDARD OFFICE PRACTICE

Lettering	The objective should be to provide distinct, uniform letters and figures with reasonable rapidity. Single stroke commercial gothic letters and figures should be used. The following alphabets indicate proper strokes. Vertical style is preferable for standard drawings, general tables, forms, charts, and work which requires a more finished appearance. The inclined style (slope 2 in 5) is preferable for working drawings, field work, and general lettering where speed is an important requisite. Lettering to read from bottom or left side of sheet as determined by the title which is always in the lower right hand corner of sheet. Height of letters and figures should be specified in twentieths so as to provide for use of horizontal lines of Standard Plate "A" profile paper.
Tables, Notes, and Material List	Tables, notes, and material lists to be placed in Right Hand upper corner of sheet.
Forms	Forms are used to assimilate information for records and comparative purposes. The weight and spacing of lines should be such as to make the form easily readible. For example - Making the third and fifth line heavy. Where much correspondence is expected in connection with the form each column should be lettered and each line numbered.
Charts - Graphs or Curves	Graphs are used where they can illustrate the relation between variable factors to greater advantage than numerical tables. The type of graph to use is dependent upon requirements. The graph should be boldly executed giving at a glance the comparison desired.
Specifications	Drawings shall specify latest revision of specification. This eliminates revision of drawing each time specification is revised. Specification shall follow the general order and form of headings as recommended by the A. R. E. A.
Sheet Number	When drawing has more than one sheet, each sheet shall be designated Sheet blank of blank. In this case it is preferable to have all sheets of the series the same size.
Symbols and Material Sections	To be standards, recommended by the A. R. E. A.
Meridian Line	To be not less than 2" long and to have letter "N" marked at its north end, but should not be so large as to be conspicuous on drawing. On large sheets the meridian should be located near the middle of the sheet.
Direction of Line	Eastbound and Southbound should be shown toward the right side of sheet and Westbound and Northbound toward the left side of sheet. Termini shall be indicated as "West to Chicago", "East to New York".
Maps and Profiles	To show nearest mile post or station, valuation station, names of all rivers and streams, degree of curve on track, and all information necessary to identify locality.
Right-of-Way Maps	Of new lines or extensions of present lines to be made on drawing size C and to be platted continuously from left to right and to further conform to I. C. C. specifications.
Scales	Drawings to be made on a sufficiently large scale so that they may be properly dimensioned. Right-of-Way Maps to be 1 inch = 200 feet. Station and Yard maps to be 1 inch = 100 feet unless otherwise indicated. Profiles to be on Standard plate "A" - 1 inch = 20 feet vertically and 400 feet horizontally.
Reduction	If a drawing is to be reduced the thickness of lines and weight of lettering on the original sheet should be increased in proportion to the weights desired on the final sheet.
Terms	For designation of steel and iron wire gage use A. S. W. G. For copper wire gage use A. W. G. Use designation of "Switch Point" instead of "Switch Rail". Use the term "Joint Bars" instead of "Splice Bars" or "Angle Bars". When it is not desirable to use the words "center line" use "℄".
General	Leave sufficient tracing cloth around drawing to provide for thumb tacking to board. On rolled drawings leave sufficient tracing cloth on outside end to designate file number and drawing number and to serve as a protection in handling. Where approval of a drawing is required the blank for the signature shall be placed immediately to the left of the title block and just above the border line. Sectioning to be on an angle of 45 degrees. Shade Rivet heads when necessary on a 45 degree line. In general no shade lines are to be used.

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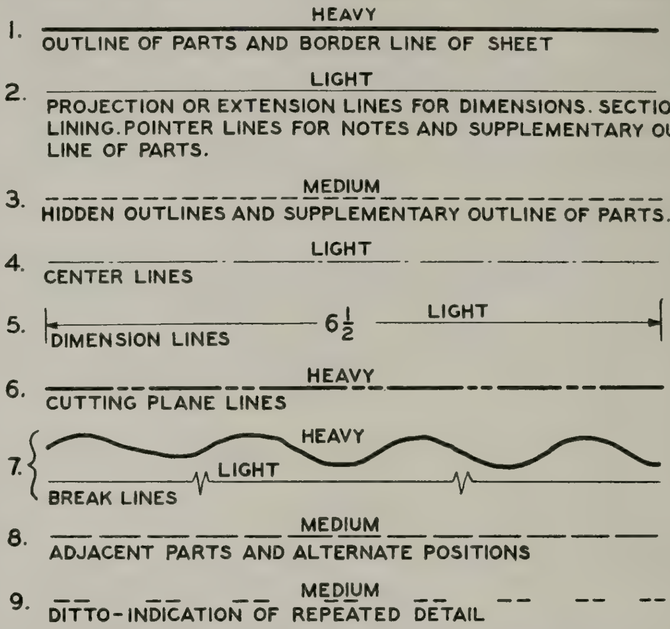
LINES AND LINE WORK



1. HEAVY
OUTLINE OF PARTS AND BORDER LINE OF SHEET

2. LIGHT
PROJECTION OR EXTENSION LINES FOR DIMENSIONS. SECTION LINING. POINTER LINES FOR NOTES AND SUPPLEMENTARY OUTLINE OF PARTS.

3. MEDIUM
HIDDEN OUTLINES AND SUPPLEMENTARY OUTLINE OF PARTS.

4. LIGHT
CENTER LINES

5. LIGHT
DIMENSION LINES

6. HEAVY
CUTTING PLANE LINES

7. HEAVY
LIGHT
BREAK LINES

8. MEDIUM
ADJACENT PARTS AND ALTERNATE POSITIONS

9. MEDIUM
DITTO-INDICATION OF REPEATED DETAIL

THREE WEIGHTS OF LINE, HEAVY, MEDIUM AND LIGHT, ARE SHOWN AND ARE CONSIDERED DESIRABLE ON FINISHED DRAWINGS IN INK, BOTH FOR LEGIBILITY AND APPEARANCE, ALTHOUGH IN RAPID PRACTICE AND IN PARTICULAR ON PENCILED DRAWINGS FROM WHICH BLUEPRINTS ARE TO BE MADE THIS MAY BE SIMPLIFIED TO TWO WEIGHTS, MEDIUM AND LIGHT.

THE ACTUAL WIDTH OF EACH TYPE OF LINE SHOULD BE GOVERNED BY THE SIZE AND STYLE OF THE DRAWING, THE RELATIVE WIDTHS OF THE LINES TO BE APPROXIMATELY THOSE SHOWN ABOVE.

THE MAIN ITEMS OR DETAILS WHICH THE DRAWING IS INTENDED TO COVER SHALL STAND OUT BOLDLY IN RELIEF BY USE OF HEAVY LINES (PER 1). ASSOCIATE PARTS OR SUPPLEMENTARY DETAIL SHALL BE DRAWN WITH LIGHT LINES (PER 2) OR MEDIUM, SHORT DASHES (PER 3)

PLAN AND ELEVATIONS OF DETAIL PARTS SHALL BE IN ACCORDANCE WITH THE ASSEMBLY DRAWING

AGREES WITH A.S.A. Z-14.1-1935

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ABBREVIATIONS

WEIGHTS AND MEASURES

TERM	ABBR.	TERM	ABBR.
Grain	gr.	Pint	pt.
Ounce	oz.	Quart	qt
Pound (s)	lb. #	Gallon	gal.
Pounds Per Square Inch	lbs. per sq. in	Second (Angle)	sec. or "
Hundredweight	cwt.	Minute (Angle)	min. or '
Ton	ton or t.	Degree (Angle)	deg. or °
Inch (es)	in or "	Second (Time)	sec.
Foot or Feet	ft. or '	Minute (Time)	min.
Yard	yd.	Hour	hr.
Mile	mile or m.	Milligramme	mg.
Link	lk.	Gramme	g.
Chain	ch.	Kilogramme	kg.
Square Inch	sq. in. □"	Millimeter	mm.
Square Foot	sq. ft. □'	Centimeter	cm.
Square Yard	sq. yd.	Meter	m
Perch	per. or p.	Kilometer	km
Rod	rd. or r.		
Acre	ac. or a.		
Cubic Inch	cu. in.		
Cubic Foot	cu. ft.		
Cubic Yard	cu. yd.		
Cubic Foot Per Second	cu. ft. per sec.		

WORK AND POWER

TERM	ABBR.	TERM	ABBR.
Brake Horse Power	B.H.P.	Revolutions	rev.
Indicated Horse Power	I.H.P.	British Thermal Unit	B.T.U.
Horse Power	H.P.	Centigrade Heat Unit	C.H.U.
Revolutions per minute	r.p.m.		

GEOMETRICAL TERMS

TERM	ABBR.	TERM	ABBR.
Centers	crs.	Diameter	dia. or d.
Center Line	C.L. or ℄	Radius	rad. or r.
Square	sq.	Round	rd.
Diagonal	diag.	Cylinder or Cylindrical	cyl.
Longitudinal	longtl	Hexagon	hex.
Linear	lin.	Octagon	oct.
Circumference	circ.		

TEMPERATURE

TERM	ABBR.	TERM	ABBR.
Centigrade	C or Cent.	Fahrenheit	F. or Fahr

GENERAL

TERM	ABBR.	TERM	ABBR.
Approved	Appr.	External	ext
Arrange (ment)	Ar.	Extruded	extrd.
Approximate	Approx.	Figure	Fig
Case Hardened	C.H.	Finished	f.
Center of Gravity	C.G	Galvanized	galv
Circular Pitch	C.P.	General	gen
Checked	Ckd.	Government	Govt
Chamfered	Chamf.	Hard Drawn	H D
Countersink	Csk	High Pressure	H.P
Drawn	Dr.	Internal	int.
Drawing	Dwg	Left Hand	L H.
Diameter	Diam	Low Pressure	L.P.
Diagram	Diag	Material	matl.
Diametrical Pitch	P D	Machinery	mach.

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GENERAL – CONT.

TERM.	ABBR.	TERM	ABBR.
Machine	mach	Right Hand	R.H
Maximum	max.	Schedule	Sch.
Minimum	min	Sheet	Sh.
Number	No	Sketch	Sk.
Passed	Psd.	Spot Faced	Spot f
Plate (Structural Steel	Pl.	Specification	Spec.
Pitch Circle	P.C.	Standard	Std.
Reference	Ref.	Tinned	Tinned
Reinforced	Reinf.	Traced	Tcd
Rolled	R.	Weight	Wt.

MAPPING AND SURVEY

TERM	ABBR.	TERM	ABBR.
Angle	An.(or) △	Point	Pt.
Abutment	abut	Point Intersection	P.I.
Arch	A.	Point of Curve	P.C.
Arroyo	Arr.	Point of Tangency	P.T.
Bench Mark	B.M.	Point of Spiral	P.S.
Blacksmith Shop	B.S.	Queenpost	q.p.
Bottom	bot	Radius	Rad
Branch	Br.	Railroad	R.R
Brick	b.	River	Riv
Bridge	br.	Road	Rd.
Building Line	B.L.	Roundhouse	R.H
Catch Basin	C.B.	South	S.
Cape	C	Street	St.
Cemetery	cem.		
Church	Ch.	School House	S.H.
Concrete	con.	Saw Mill	S.M
Contour	cont.	Station	Sta.
Covered	cov.	Stone	Stn
Creek	cr.	Stream	Str.
Crossing (R.R.) (Hgw.)	Xing.	Subdivision	Subdv.
Crossover	X'over	Tangent	T.
Chord	Ch.	Toll Gate	T.G.
Degree of Curve	D.	Toll Bridge	T.B.
Drug Store	D.S	Transit Point	Tr.P.
Deflection	Def	Trestle	Tres.
East	E.	Truss	tr.
Estuary	Est.	Undergrade Crossing	Ung. Xing.
External	Ext.	Water Tank	W.T.
Ford	f.	Waterworks	Ww.
Fort	Ft.	West	W.
Garage	G.	Wood	w.
General Store	G.S.	Azimuth	Az.
Girder	gir.	Curb Line	Cb. L
Grist Mill	G.M.	Manhole	Mh
Grade Crossing	G.Xing	Center Line	C.L or ℄
Iron	I		
Island	Is.		
Junction	Jct.		
King Post	Kp.		
Lake	L		
Latitude	Lat		
Landing	Ldg.		
Life Saving Station	L.S.S		
Lighthouse	L.H.		
Longitude	Long.		
Mountain (s)	Mt.-Mts		
North	N		
Not fordable	n.f.		
Overhead Crossing	Ovh Xing		
Park	P		
Pier	Pr		
Plank	pk		

⑩

MATERIALS

TERM	ABBR.	TERM	ABBR.
FERROUS—		Mild Steel	M.S.
Cast Iron	C.I.	Nickel Chrome Steel	Ni.Cr.S
Malleable Iron	M.I.	Nickel Steel	Ni.S.
Sheet Iron	Sh.I.	Sheet Steel	Sh.S.
Wrought Iron	W.I.	Spring Steel	Spr. S
* Steel (Rolled)	Steel	Structural Steel	Str. S.
Cast Steel	C.S.	Machine Steel	Mach. S.
Forged Steel	F.S.	Titanium Steel	Ti. S.
Manganese Steel	Mn.S.	Vanadian Steel	V.S.
Molybdenum Steel	Mo.S		
NON-FERROUS			
Aluminium	Al.	Platinum	Pt.
* Bronze	Bronze	German Silver	Ger. Sil.
Phosphor Bronze	P.B	Copper	Cu.
Manganese Bronze	Mn.B.	Lead	Ld.
Gunmetal	Gm.	* Tin	Tin
Brass	Br.	White Metal	W.M
Naval Brass	N.Br.	Zinc	Zn.
Rolled Naval Brass	R.N.Br.		
NON-METALLIC			
Asbestos	Asb	Ice	Ice
Carbon	C.	Limestone	Ls.
* Cork	Cork	* Mica	Mica
* Coal	Coal	Porcelain	Por.
Earth	Eth.	Rubber	Ru.
Excelsior	Excl	Sandstone	Sds.
Granite	Gr	Slate	Sl.
Glass	Gl.		
Hardwood	Hw.	* No Abbreviation Necessary	

GAUGES

TERM	ABBR.
AMERICAN SHEET AND WIRE GAUGE	A.S.W.G.
BIRMINGHAM WIRE GAUGE	B.W.G.
BROWN AND SHARPE'S AND AMERICAN (WIRE) GAUGE	A.W.G.
IMPERIAL STD. WIRE GAUGE	S.W.G.
UNITED STATES STD. SHEET AND PLATE GAUGE	U.S.S.G.

BOLTS-NUTS-RIVETS

TERM	ABBR.	TERM	ABBR.
BOLTS			
Button Head	B.H.	Machine	M.B
Carriage	Car.B.	Neck	Nk.
Elliptical Head	Ellip.H	Oval Neck	O.N.
Hexagon Head	Hex.H.	Round Head	R.H.
Lag Bolt	Lag B	Square Head	S.H
NUTS			
Castle	Cst.	Jam	Jam
Cold Punched	C.P.	Regular	Reg
Hexagon	Hex	Semi-Finished	S.F.
Hot Pressed	H.P.	Thin	Thin
RIVETS			
Button Head	B.H	Flat Head	F.H.
Cone Head	C.H	Pan Head Swelled Neck	P.H.S.N
Countersink Head	Csk.H	Round Head	R.H.

⑪

ARRANGEMENT OF VIEWS

A. This outline is not intended to be an exact guide to be followed in the preparation of engineering drawings but simply to call forcefully to the attention of those responsible for the preparation of drawings the need for simplification and standardization.

B. The third angle or American system of orthographical projection shall be used, except as designated below:

(a) Definition: Orthographical projection is the method of representing the exact shape of an object in two or more views or planes generally at right angles to each other, by dropping perpendiculars from the object to the planes.

C. Drawings may be divided into two groups.

(a) Assembly (with sectioning).

(b) Detail and Sections (with sectioning).

D. Generally the assembly shall occupy the first sheet of a series. The detail shall follow in order according to size and shape, location on assembly or some natural sequence. All detail shall be shown preferably in the same scale.

E. General arrangement of views shall be in accordance with Sheet 13.

(a) Sufficient views shall be shown to clearly represent the subject and to allow for proper dimensioning.

(b) Designation and order of usefulness.

1. Top View.

2. Front View.

3. Side View (Right or Left).

4. Rear View.

5. Bottom View.

F. The following types of projection may be used where special conditions require them: Isometric, Diametric, and Oblique. In architectural drawings; perspective sketching.

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DRAWINGS AND DRAFTING ROOM PRACTICE - 1935

Figures On Sheets-14-15

SECTIONAL VIEWS

General - Sectional views or "sections" should be used when the interior construction cannot be shown clearly by outside views. A sectional view should be made as if on that view the front part of the object were cut or broken away. The exposed cut surface of the material is indicated by section lining or cross hatching with uniformly spaced fine lines. Hidden lines and details beyond the cutting plane should be omitted unless required for the necessary description of the object.

Symbolic section lining may be used when it is desired to call special attention to, or to identify certain parts. Reference letters shall be used to indicate the heat treatment which the material is to receive.

Cutting Plane - Indicate by a heavy broken line consisting of one long and two short dashes alternately spaced, and lettered at the ends as A-A - Figure 1. Arrows are used to indicate the direction in which the section is viewed. On simple symmetrical objects the heavy line, letters and arrows may be omitted. It is not necessary that the cutting plane be a single continuous plane, it may be bent or offset if by so doing the construction can be shown to better advantage as for example A-A or B-B Fig. 1. When the cutting plane extends entirely across the object a "full section" is obtained. A symmetrical object may be drawn as a "half section", showing one half, up to the center line, in section and the other half in full, Fig. 2.

Revolved Sections - These show the shape of the cross-section on the longitudinal view of a part, such as the arm of a wheel, the cutting plane being rotated in place, Fig. 3. "Detail sections" should be drawn similarly except that they are placed to one side and often are made to larger scale than the view on which they are indicated. See Fig. 15 Section B-B.

⑫

Other types of Sections - Broken-out Sections should be used where a sectional view of only a portion of the object is needed, Fig. 4. Phantom sections or dotted sections are outside views with the interior construction shown by dotted crosshatching. Their use sometimes saves the making of an extra view Fig. 5.

Section Lining - Section lining should be made with light parallel lines at an angle of 45 degrees with the border line of the drawing and spaced 1/20 in. (Plate A profile paper). Two adjacent parts should be sectioned in opposite directions. A third, adjacent to both, should be sectioned at 30 or 60 degrees. If cut in more than one place the sectioning of any part should be the same in direction and spacing. If the shape or position of the part would bring 45 degree sectioning parallel or nearly parallel to one of the sides, another angle should be chosen.

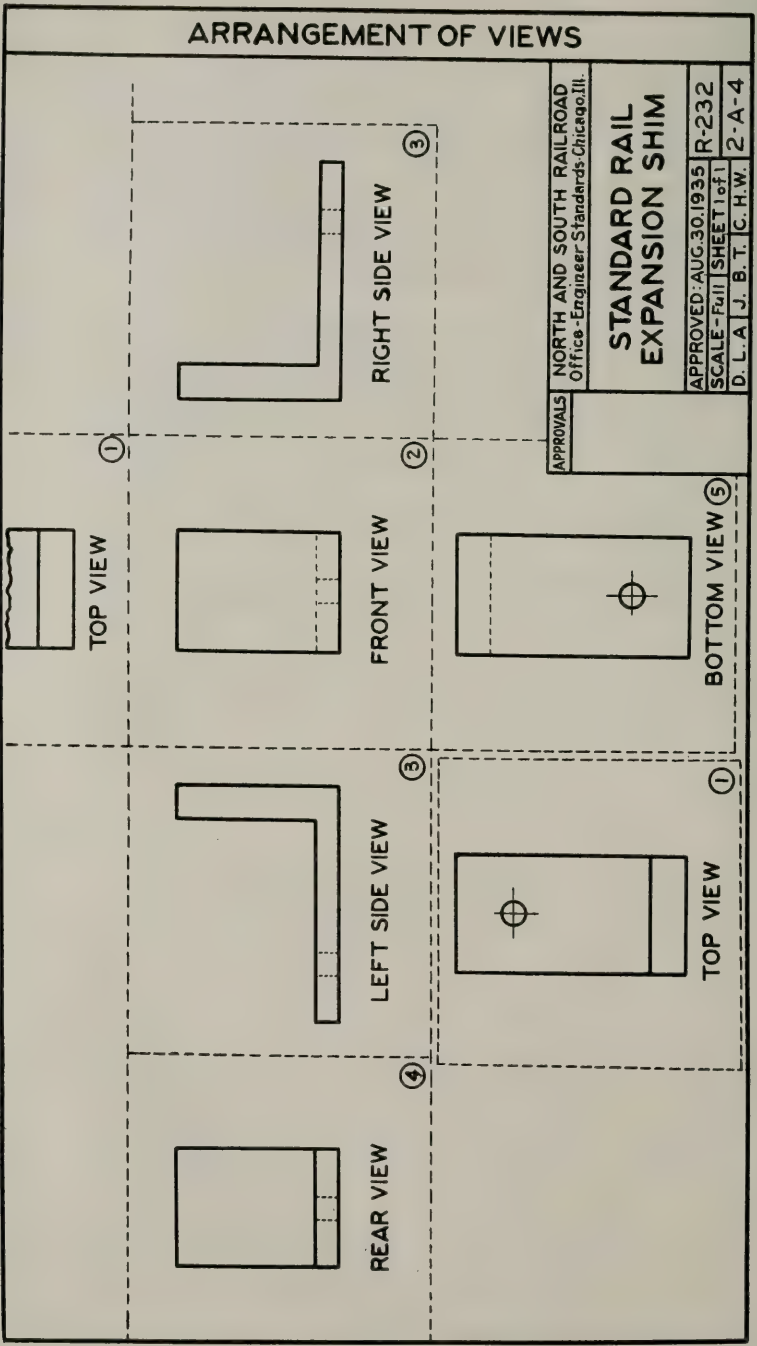
Thin Sections - Sections which are too thin for line sectioning may be shown solid, such as structural shapes, sheet metal, packing, gaskets, etc. Where two or more thicknesses are shown a white line should be left between them, Fig. 6.

Exceptions - There is one important violation of the conventional theory which is made in the interest of clearness. When the section plane passes through a rib, web or similar parallel element, section lines should be omitted from those parts, Fig. 1 and Fig. 7. Shafts, bolts, nuts, rods, rivets, keys, pins and similar parts whose axes lie in the cutting plane should not be sectioned, Fig. 8.

When the true projection of a piece may be misleading, parts such as ribs or arms should be rotated until parallel to the plane of the section or projection. The representation in Fig. 1 and 9, for example, is preferred rather than the true projection.

Drilled flanges in elevation or section should show the holes at their true distance from the center rather than the true projection, Fig. 7.

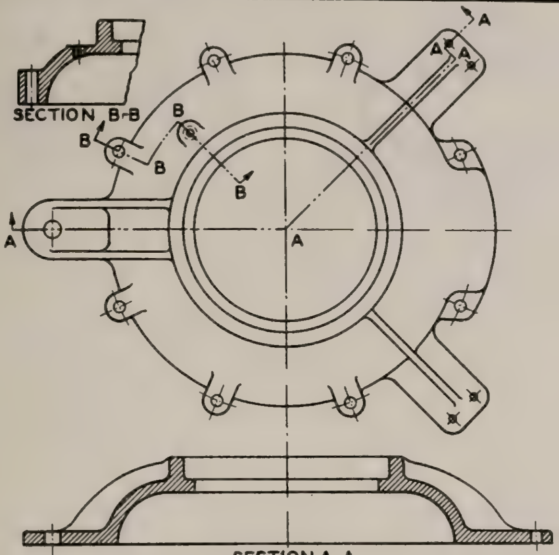
⑬



ARRANGEMENT OF VIEWS

⑭

SECTIONAL VIEWS



SECTION A-A

FIG. 1

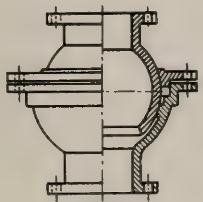


FIG. 2

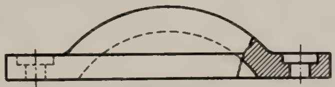


FIG. 4

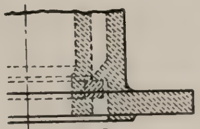


FIG. 5

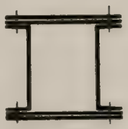


FIG. 6

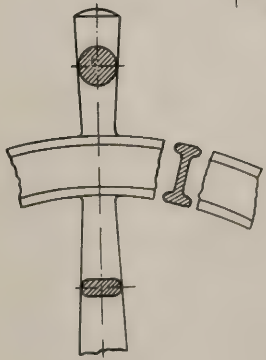


FIG. 3

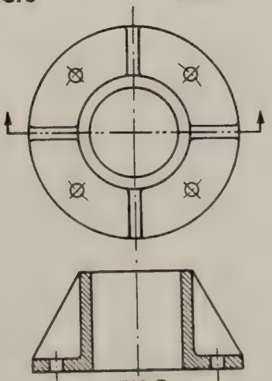


FIG. 7

REPRINT FROM A S.A. Z-14 1-1935

⑮

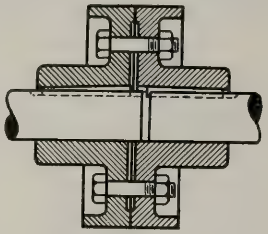


FIG. 8

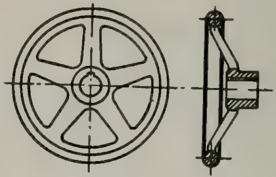


FIG. 9

REPRINT FROM A.S.A. Z-14.1-1935

Appendix D

(C–1) RECOMMENDED PRACTICE TO BE FOLLOWED WITH RESPECT TO MAINTENANCE OF WAY ACCOUNTS AND STATISTICAL REQUIREMENTS

W. F. Cummings, Chairman, Sub-Committee; Anton Anderson, D. L. Avery, E. V. Braden, P. O. Ferris, W. E. Gardner, W. M. Ludolph, W. S. McFetridge, H. L. Restall, C. K. Smith, F. X. Soete, D. C. Teal, A. P. Weymouth.

The assignment of this Sub-Committee has been a continuing one (under various wordings of assignments) for a number of years. In 1925 the Committee presented as a guide a chart showing an accounting and statistical report procedure for the Maintenance of Way Department. Since that time this chart has been followed and forms designed to furnish much of the data called for have been presented.

The chart was presented at a time when the tendency was toward a divisional system of accounting and it was set up on that basis. Since that time, however, there has been a greater tendency toward centralized accounting or some form of it. For that reason the Sub-Committee presents herewith as Exhibit 1 the chart referred to set up to conform to either a divisional or centralized accounting system, with a few additions, changes and notes to bring it up to date.

As will be seen by reference to the chart, the forms designed to cover Blocks 1 to 10 inclusive, 37 and 38 have been presented from time to time.

The Committee this year presents also three forms as follows:

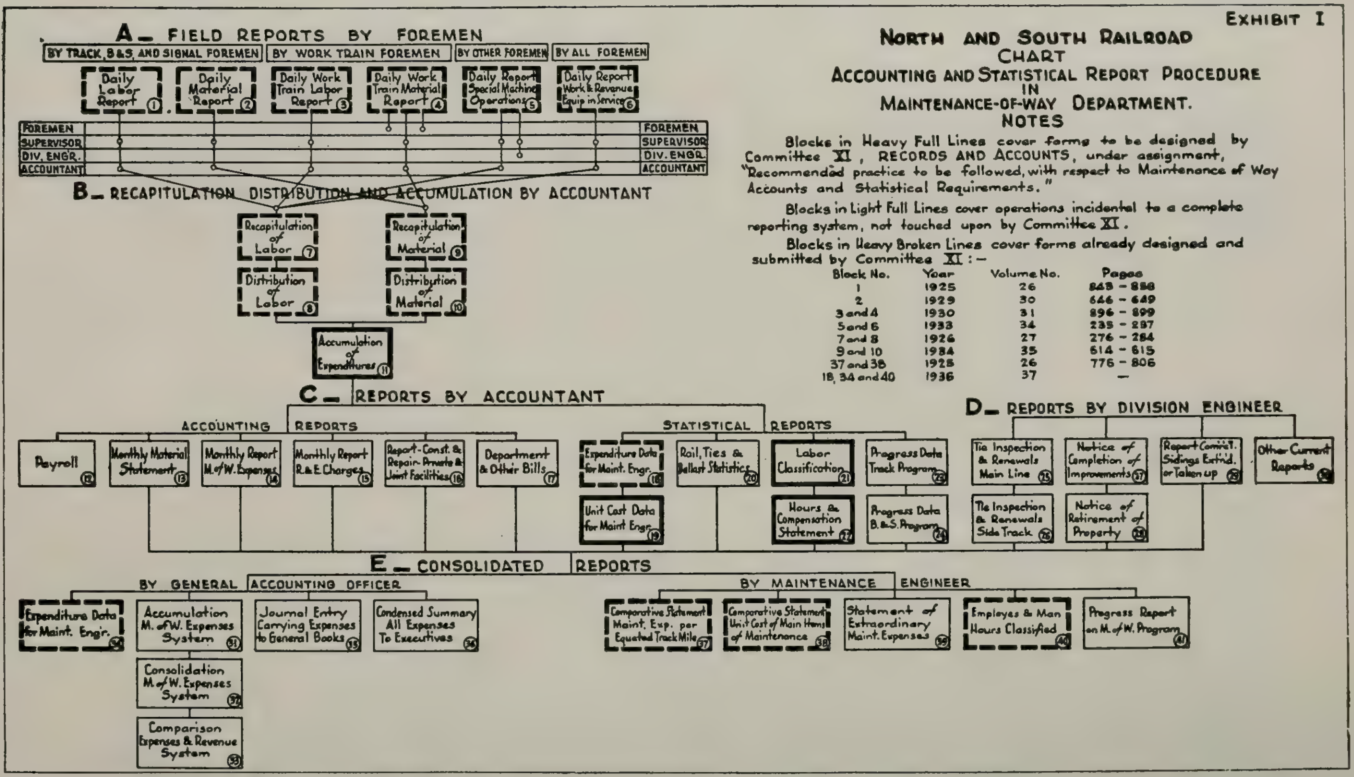
(1) As Exhibit 2 a form entitled, "Divisional analysis of charges to operating expenses—Maintenance of Way and Structures". This form is designed to be prepared by the Accounting Department from underlying reports and is for the information of the Maintenance Engineer. The form furnishes data called for in Block 18.

(2) As Exhibit 3 a form entitled, "System analysis of charges to operating expenses—Maintenance of Way and Structures." This form is likewise made in the Accounting Department. As the heading implies it is for the entire system and is for the use of the Maintenance Engineer. The several columns provide for segregation of charges by designated divisions and by other engineering forces not organized by divisions. The form furnishes data called for in Block 34.

(3) As Exhibit 4 a form entitled, "Man-hour report", showing information as to number of men, straight time, overtime and total time. This information is classified between track, bridge and building, signal and miscellaneous forces with further subdivision according to occupations. Provision is made for explanation of overtime on the reverse side of the sheet, where the overtime man-hours may be divided between time paid for at pro rata (Pro.) straight time rates and time paid for at punitive rate (Pun.) in excess of straight time rates. The form is prepared by the Maintenance of Way Department for the information of the Maintenance Engineer, and while it is headed as reporting information for a division, it is adaptable as a system report as well. The form furnishes data called for in Block 40.

The report is presented as information.

EXHIBIT I


A — FIELD REPORTS BY FOREMEN
BY TRACK, B&S, AND SIGNAL FOREMEN
BY WORK TRAIN FOREMEN
BY OTHER FOREMEN
BY ALL FOREMEN
Daily Labor Report ①
Daily Material Report ②
Daily Work Train Labor Report ③
Daily Work Train Material Report ④
Daily Report Special Machine Operations ⑤
Daily Report Work & Revenue Equip. in Service ⑥
FOREMEN
SUPERVISOR
DIV. ENGR.
ACCOUNTANT
B — RECAPITULATION DISTRIBUTION AND ACCUMULATION BY ACCOUNTANT
Recapitulation of Labor ⑦
Distribution of Labor ⑧
Recapitulation of Material ⑨
Distribution of Material ⑩
Accumulation of Expenditures ⑪
C — REPORTS BY ACCOUNTANT
ACCOUNTING REPORTS
Payroll ⑫
Monthly Material Statement ⑬
Monthly Report M. of W. Expenses ⑭
Monthly Report R. & E. Charges ⑮
Report-Const. & Repair-Private & Joint Facilities ⑯
Department & Other Bills ⑰
STATISTICAL REPORTS
Expenditure Data for Maint. Engr. ⑱
Unit Cost Data for Maint. Engr. ⑲
Rail, Ties & Ballast Statistics ⑳
Labor Classification ㉑
Hours & Compensation Statement ㉒
Progress Data Track Program ㉓
Progress Data B. & S. Program ㉔
D — REPORTS BY DIVISION ENGINEER
Tie Inspection & Renewals Main Line ㉕
Tie Inspection & Renewals Side Track ㉖
Notice of Completion of Improvements ㉗
Notice of Retirement of Property ㉘
Report Const. Sidings Ext'nd. or Taken up ㉙
Other Current Reports ㉚
E — CONSOLIDATED REPORTS
BY GENERAL ACCOUNTING OFFICER
Expenditure Data for Maint. Engr. ㉞
Accumulation M. of W. Expenses System ㉛
Consolidation M. of W. Expenses System ㉜
Comparison Expenses & Revenue System ㉝
Journal Entry Carrying Expenses to General Books ㉟
Condensed Summary All Expenses To Executives ㊱
BY MAINTENANCE ENGINEER
Comparative Statement Maint. Exp. per Equated Track Mile ㊲
Comparative Statement Unit Cost of Main Items of Maintenance ㊳
Statement of Extraordinary Maint. Expenses ㊴
Employes & Man Hours Classified ㊵
Progress Report on M. of W. Program ㊶

NORTH AND SOUTH RAILROAD
CHART
ACCOUNTING AND STATISTICAL REPORT PROCEDURE
IN
MAINTENANCE-OF-WAY DEPARTMENT.

NOTES

Blocks in Heavy Full Lines cover forms to be designed by Committee XI, RECORDS AND ACCOUNTS, under assignment, "Recommended practice to be followed, with respect to Maintenance of Way Accounts and Statistical Requirements."

Blocks in Light Full Lines cover operations incidental to a complete reporting system, not touched upon by Committee XI.

Blocks in Heavy Broken Lines cover forms already designed and submitted by Committee XI:—

Block No.	Year	Volume No.	Pages
1	1925	26	843 – 858
2	1929	30	646 – 649
3 and 4	1930	31	896 – 899
5 and 6	1933	34	235 – 287
7 and 8	1926	27	276 – 284
9 and 10	1934	35	614 – 615
37 and 38	1928	26	776 – 806
18, 34 and 40	1936	37	—

Size 11" x 17" – Exhibit 2

NORTH AND SOUTH RAILROAD

DIVISIONAL ANALYSIS OF CHARGES TO OPERATING EXPENSES – MAINTENANCE OF WAY AND STRUCTURES

DIVISION ____________

MONTH OF ____________ 19____

	DIRECT MAINTENANCE				CONSTRUCTION OPERATING					DIVISION		DEPARTMENTS			TOTAL	
ACCOUNT	LABOR	MATERIAL	WORK TRAINS	OTHER CHARGES	RETIREMENTS	BRIDGE PROGRAM	BALLAST PROGRAM	RAIL PROGRAM	OTHER A.F.E. CHARGES	OFFICERS	EXPENSES	MECHANICAL	TRANS	OTHER	AMOUNT	ACC'T
201																201
202																202
206																206
208																208
212																212
214																214
216																216
218																218
220																220
221																221
223																223
225																225
227																227
229																229
231																231
233																233
235																235
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257																257
259																259
261																261
263																263
265																265
266																266
267																267
269																269
271																271
272																272
273																273
274																274
275																275
276																276
277																277
278																278
279																279
280																280
TOTALS																

DATE ____________________

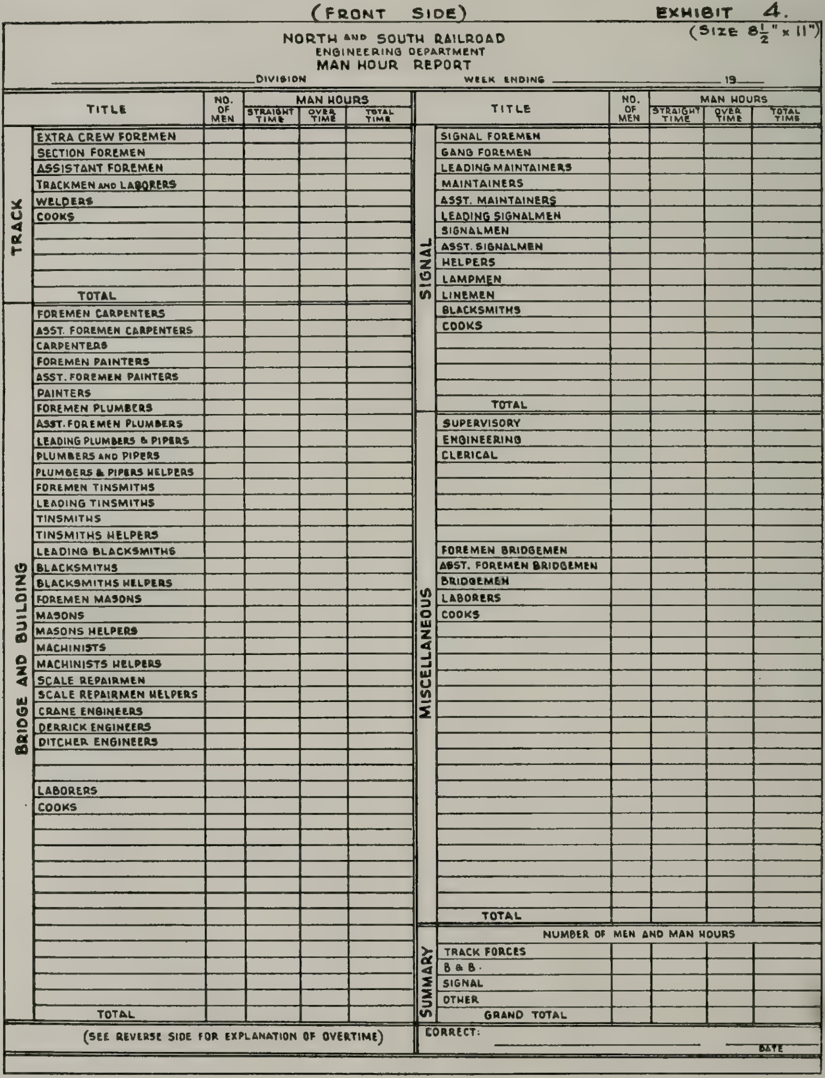
ACCOUNTING DEPARTMENT

CORRECT ____________________

APPROVED ____________________

(FRONT SIDE)

EXHIBIT 4.
(Size 8½" x 11")



NORTH AND SOUTH RAILROAD
ENGINEERING DEPARTMENT
MAN HOUR REPORT

________ DIVISION WEEK ENDING ________ 19__

	TITLE	NO. OF MEN	MAN HOURS		
			STRAIGHT TIME	OVER TIME	TOTAL TIME
TRACK	EXTRA CREW FOREMEN				
	SECTION FOREMEN				
	ASSISTANT FOREMEN				
	TRACKMEN AND LABORERS				
	WELDERS				
	COOKS				
	TOTAL				
BRIDGE AND BUILDING	FOREMEN CARPENTERS				
	ASST. FOREMEN CARPENTERS				
	CARPENTERS				
	FOREMEN PAINTERS				
	ASST. FOREMEN PAINTERS				
	PAINTERS				
	FOREMEN PLUMBERS				
	ASST. FOREMEN PLUMBERS				
	LEADING PLUMBERS & PIPERS				
	PLUMBERS AND PIPERS				
	PLUMBERS & PIPERS HELPERS				
	FOREMEN TINSMITHS				
	LEADING TINSMITHS				
	TINSMITHS				
	TINSMITHS HELPERS				
	LEADING BLACKSMITHS				
	BLACKSMITHS				
	BLACKSMITHS HELPERS				
	FOREMEN MASONS				
	MASONS				
	MASONS HELPERS				
	MACHINISTS				
	MACHINISTS HELPERS				
	SCALE REPAIRMEN				
	SCALE REPAIRMEN HELPERS				
	CRANE ENGINEERS				
	DERRICK ENGINEERS				
	DITCHER ENGINEERS				
	LABORERS				
	COOKS				
	TOTAL				

(SEE REVERSE SIDE FOR EXPLANATION OF OVERTIME)

	TITLE	NO. OF MEN	MAN HOURS		
			STRAIGHT TIME	OVER TIME	TOTAL TIME
SIGNAL	SIGNAL FOREMEN				
	GANG FOREMEN				
	LEADING MAINTAINERS				
	MAINTAINERS				
	ASST. MAINTAINERS				
	LEADING SIGNALMEN				
	SIGNALMEN				
	ASST. SIGNALMEN				
	HELPERS				
	LAMPMEN				
	LINEMEN				
	BLACKSMITHS				
	COOKS				
	TOTAL				
MISCELLANEOUS	SUPERVISORY				
	ENGINEERING				
	CLERICAL				
	FOREMEN BRIDGEMEN				
	ASST. FOREMEN BRIDGEMEN				
	BRIDGEMEN				
	LABORERS				
	COOKS				
	TOTAL				
SUMMARY	NUMBER OF MEN AND MAN HOURS				
	TRACK FORCES				
	B & B				
	SIGNAL				
	OTHER				
	GRAND TOTAL				

CORRECT: ________ ________ DATE

(REVERSE SIDE) EXHIBIT 4.

EXPLANATION OF OVERTIME HOURS

_____ DIVISION WEEK ENDING _____ 19__

ITEM	TRACK SUPERVISORS DISTRICTS												B. & B.		SIGNAL		TOTALS	
	DIST. 1		DIST. 2		DIST. 3		DIST. 4		DIST. 5		DIST. 6							
	PRO.	PUN.	PRO.	PUN.	PRO.	PUN.	PRO.	PUN	PRO.	PUN.	PRO.	PUN.	PRO.	PUN.	PRO.	PUN.	PRO	PUN.
TOTALS																		

REMARKS

EXHIBIT 3
SIZE - 11" x 17"

NORTH AND SOUTH RAILROAD

SYSTEM ANALYSIS OF CHARGES TO OPERATING EXPENSE—MAINTENANCE OF WAY AND STRUCTURES

(INCLUDING CONSTRUCTION OPERATING, OTHER DEPTS. AND GENERAL EXPENSES)

MONTH OF 19

Group	Description	____Div.	____Div.	____Div.	____Div.	Signal Construction	Electrical & Work Equipment	General	Total	
1.	DIRECT MAINTENANCE	Amount	Amount	Amount	Amount	Amount	Amount	Amount		
	(A) Labor									
	(B) Material #1									
	(C) Work Trains									
	(D) Other Charges									
	Total									
2.	CONSTRUCTION OPERATING									
	(A) Retirements									
	(B) Bridge Program #1									
	(C) Ballast " #1									
	(D) Rail " #1									
	(E) Other (A.F.E.) Charges #1									
	Total									
3.	EQUALIZATION (Ties) (280)									
4.	General Engineering Dept.									
	(A) Officers Salaries (201-A)									
	(B) Semi-Monthly Employes (201-A)									
	(C) Other Expenses (201-B)									
	Total									
5.	OTHER MISC. CHARGES									
	(A) Personal Injuries (274)									
	(B) Joint Facilities - Dr. (278)									
	(C) " " Cr. (279)									
	(D) Accts. Receivable									
	(E) Mech. Dept. #2									
	(F) Trans. Dept.									
	(G) Dining Car Service									
	(H) General Offices									
	(I) Insurance (275)									
	Total									
6.	GRAND TOTAL M. of W. & S.									

Date ______________ 193__
Accounting Dept.

#1 includes $ ______ Store Expense
#2 " $ ______ Material

Approved ______________

Appendix E

(D-1) CONSTRUCTION REPORTS AND RECORDS

B. A. Bertenshaw, Chairman, Sub-Committee; Anton Anderson, D. L. Avery, S. H. Barnhart, A. M. Blanchard, V. H. Doyle, C. C. Haire, J. H. Hande, A. T. Hopkins, W. W. James, W. M. Ludolph, W. S. McFetridge, A. T. Powell, A. P. Weymouth.

General

This is a new assignment, and the Committee decided to study and report this year on the following:

1. Sidetrack Records
2. Bridge Records
3. Building Records

1. Sidetrack Records

Information should be available at all times to properly identify sidetracks and show their length, ownership, and maintenance obligations. Exhibit "A" is presented, illustrating a method by which such data may be recorded.

Each sidetrack should be numbered in order to establish its identity. One method of numbering is to begin at one end of a valuation section or operating division and number the tracks consecutively through to the other end of the valuation section or operating division. This method has the advantage of simplicity and also that there cannot be more than one track bearing the same number on any valuation section or operating division, and therefore the single number positively identifies the track. The disadvantage to this method is that after numbers have once been assigned and additional tracks are built, the number assigned to the new tracks may be widely different from the numbers originally assigned to tracks in the same vicinity. For example, a newly constructed track might be assigned Number 210 and be parallel with and alongside of track Number 3, so that the numbers under this method do not offer much assistance as regards physical location, except with the aid of an index.

Another method is to number consecutively, beginning with "1" at each location. This has the advantage of having all track numbers at a given location in sequence and, having given the location, makes it easier to locate any individual track. The disadvantage is that of having several tracks on a valuation section or operating division with the same number.

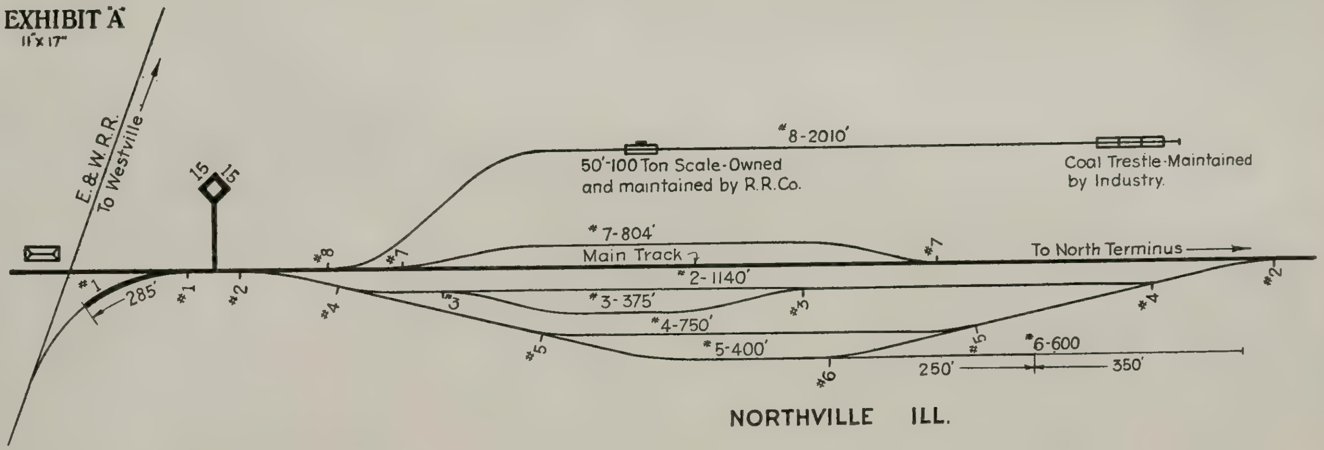
As a further aid to location and identification, all tracks on the north or east side of the main track may be assigned odd numbers only, while all on the south or west side of the main track may be assigned even numbers only.

When an entire track is retired and not replaced, its number should not be assigned to any other track.

Regardless of which method of numbering is adopted, a track diagram, not drawn to scale, similar to Exhibit "A", should be maintained for each location or track layout. There is always more or less confusion as to where a certain sidetrack begins and ends; therefore the number of the track should be placed opposite each point of switch and the number and length of the track placed somewhere near its center, as illustrated on the exhibit.

In addition to the diagram on Exhibit "A" there is shown a table, in separate columns of which are recorded the number of the track, its total length, the length owned by the railroad, the contract reference, and information as to who has charge of maintenance and at whose expense it is performed. When changes are made to any track, corresponding changes should be made both to the diagram and the table, and the sheet marked "Corrected" or "Revised" as of the date of the change.

EXHIBIT "A"
11" x 17"



Track No.	Length-Ft.		Con-tract	Maintenance		Remarks
	Total	Owned by R.R. Co.		In Charge of	At Expense of	
1	285	285	#167	R.R Co.	R.R.Co.	
2	1140	1140	None	,,	,,	
3	375	375	,,	,,	,,	
4	750	750	,,	,,	,,	
5	400	400	,,	,,	,,	
6	600	250	#242	250 ,, 350 ,,	,, Industry	
7	804	804	#145	R.R Co.	R.R.Co.	
8	2010	2010	#146	,,	,,	

NORTH & SOUTH R.R.
TRACK DIAGRAM
NORTHVILLE, ILL.
Sept. 11, 1935 - No Scale
Office of

Some roads may wish to record additional information in this table, such as the weight of rail, kind, length, and size of ties, and kind and depth of ballast, in which case the table may be expanded by adding columns with appropriate headings, but it is not thought desirable to make this record too complex or burdensome to maintain, and this additional information might better be kept in some other record.

2. Bridge Records

The Manual of 1929 at page 734, under "Masonry", states that "in all cases give quantities in final estimate." As indicated below, these should be arranged in tabular form on the plans revised to show masonry as built.

QUANTITIES AS BUILT

Item	*Unit*	*Number of Units*			
		North Abutment	*South Abutment*	*Pier No.——*	*Total*
Excavation—Earth—Dry	Cu.yd.				
Excavation—Earth—Wet	Cu.yd.				
Excavation—Rock—Dry	Cu.yd.				
Excavation—Rock—Wet	Cu.yd.				
Backfill	Cu.yd.				
Cofferdam Timber	M.B.M.				
Steel Sheet Piling—Left in	Lb.				
Steel Sheet Piling—Removed	Lb.				
Puddledam Material	Cu.yd.				
Foundation Piling ———— ...	L.F.				
Grillage	M.B.M.				
Riprap	Cu.yd.				
Concrete Class ————	Cu.yd.				
Concrete Class ————	Cu.yd.				
Concrete Class ————	Cu.yd.				
Reinforcing—Bars	Lb.				
Reinforcing—Rail	Lb.				
Reinforcing ————					
Waterproofing	Sq.yd.				
————					
————					

Other information called for in the "Manual" reference above should either be included with the above table or placed on the plans immediately adjacent to it, as follows:

Survey Station at center of Bridge
Elevation—Base of Rail
Elevation—Bridge Seat
Elevation—Top of Footing
Elevation—Bottom of Footing
Elevation—Surface of Water
Elevation—Ground Line
Length of Piles
Description and elevation of Bench Mark

3. Building Records

For accurate accounting and valuation records, proper identification of buildings is necessary, and in any system of building records one of the greatest difficulties encountered is that of identification. This, of course, does not apply to larger buildings such as stations and enginehouses, but in large towns and at terminals there is a large number of minor structures that have no marked characteristic either as to form or use, and which are frequently moved, altered, or their use changed, making identification by use, location or description uncertain. This difficulty may be overcome by a system of numbering all buildings.

There are various methods of numbering buildings, the principal ones falling generally into one of the following:

(a) Consecutive numbering carried through from one end of a valuation section or operating division to the other;
(b) Consecutive numbering in each town or city;
(c) Consecutive numbering in each mile.

Under Method "a" there would be no more than one building in any valuation section or operating division having the same number, and the number would have no prefix or suffix. This method makes for simplicity, but, as mentioned above for sidetracks, buildings in the same town might have widely different numbers, and the number would have no bearing on the location.

Using Method "b", each town or city is assigned a number; if the transportation department has already assigned numbers to the towns these should be adopted. The number of the town precedes each building number in that town. This method has the advantage that the building number with the prefixed town number locates the building to the nearest town. The disadvantage of this method is that it increases the size of the number to be placed on the buildings in the field and is a little more cumbersome for handling in telegraphic messages and correspondence.

Method "c" is similar to Method "b" except that the location is further restricted to the mile, and it naturally follows that there would be fewer buildings on any valuation section or operating division having the same prefix number, hence a more restricted location and somewhat easier identification.

Minor structures such as car bodies and outhouses are often placed as auxiliary to or near some large or important building; these may be assigned the same number as the main building with a sub-letter or number suffix, but this is not recommended. When a building is retired and not replaced its number should be retired, that is, its number should not be assigned to some other building.

Even after a method of numbering buildings has been decided on, there is still the problem of choosing a way of affixing the number to the building itself. Following are methods which readily suggest themselves:

(1) Stencil in contrasting colors on the building itself;
(2) Paint number on separate board or thin metal plate, and attach to building;
(3) Cast, stamped or embossed metal figures attached to building.

No. 1 requires a painter and stencil outfit at each building, while Nos. 2 and 3 may be made at company shops and attached to the building by anyone assigned. Nos. 2 and 3 should use wood screws for fastening, to prevent loss through plates or boards working loose. No. 3 is of the more permanent nature, and therefore more likely to survive fire and preserve identification.

Building numbers should be large enough to be easily legible at a reasonable distance. For small buildings the numbers should be about four inches high, and for large buildings about six inches high. They should be placed about seven feet above the ground or platform level. Numbers should be affixed to the building in accordance with some fixed plan as to location, so that anyone looking for a number would know at once where to find it. The most general locations are:

(1) Main track side of building;
(2) End of building near corner farthest from main track;
(3) On side opposite main track.

When placed on the main track side of the building the number may be read from passing trains or motor cars, which is a decided advantage, but this is more than offset by the disfiguration of the front or face of the building. The main reason for placing them on the back or side opposite the main track is to do away with the disfiguration on all parts of the building visible from the main track. On small buildings, such as small station buildings, section houses and car bodies, one number should be sufficient. On large station and office buildings and freight houses two sets of numbers should be placed on each building, while on large shops and enginehouses four sets of numbers should be affixed.

A record of all buildings should be kept, giving the information necessary for maintenance, tax, and insurance purposes, such as use, size, year built, kind of construction, taxing district, fire protection, etc. This record will be made the subject of further study.

Conclusion

Your Committee does not deem it advisable to recommend a uniform system of numbering sidetracks and buildings, but does wish to stress the importance of some system as a means of lessening the difficulty of identification. It recommends that this report be accepted as information and the subject continued for further study.

Appendix F

(E-1) METHODS AND FORMS FOR GATHERING DATA FOR KEEPING UP TO DATE THE PROPERTY RECORDS OF RAILWAYS WITH RESPECT TO VALUATION, ACCOUNTING, DEPRECIATION AND OTHER REQUIREMENTS

C. A. Knowles, Chairman, Sub-Committee; B. A. Bertenshaw, S. H. Barnhart, P. D. Coons, V. H. Doyle, P. O. Ferris, W. E. Gardner, A. T. Hopkins, W. W. James, F. C. Kane, W. R. Kettenring, P. R. Leete, Henry Lehn, W. S. MacCulloch, E. W. Metcalf, F. J. Nevins, H. L. Restall, D. W. Smith, James Stephenson, H. J. Stroebel, and Louis Wolf.

(1) Valuation

During the past year a plan for co-operation between this Committee and the Finance, Accounting, Taxation and Valuation Department, Association of American Railroads was developed and put into effect. Under this plan the Committee in co-operation with the valuation staff of that Department (1) collects information of benefit to carriers, relative to valuation matters and especially such matters as pertain to the Interstate Commerce Commission's valuation orders and methods and (2) develops, where practicable, simplified practices for recommended use by carriers; the information so collected, or developed, is currently given to the carriers in circulars issued by the Vice-President of the aforementioned Department of the Association of American Railroads and the developments of the year are summarized in the Committee's annual report to the American Railway Engineering Association in convention. Under this plan all railroad representatives, interested in valuation, whether or not members of the American Railway Engineering Association, have a facility by which they may keep themselves informed in respect to valuation subjects.

In this year's work the Committee has proceeded in accordance with the plan and as a result a circular was issued by E. H. Bunnell, Vice-President, Association of American Railroads, under date of December 10, 1935, and sent to the member railroads of that association. A copy of the circular is submitted herewith in Exhibit No. 1.

The two following matters are of especial interest.

(A) Supreme Court Decision

The United States Supreme Court, June 3, 1935, rendered a decision of importance in the valuation of public utility property. In this decision which arose in a case brought to test the constitutionality of a value placed on the property of the Chesapeake and Potomac Telephone Company, by the Maryland Public Service Corporation, the Court condemned the use of general price indices as the sole means of bringing the valuation of public utility properties up to date. The Court also decided that the lower Court that heard the case erred in attempting to set a value by deducting the company's depreciation reserve from its book cost, adding to the difference an allowance for working capital. In rejecting both of these methods, the Supreme Court repeated what it had often said before—namely, that all elements of value must be taken into consideration. Three of the Justices dissented. The full text of the decision and the footnotes appended to the dissenting opinion give quite a complete description of the character of the price indices and the manner in which they were used by the Public Service Commission.

(B) Bringing Valuations Up to Date by I.C.C.

The Interstate Commerce Commission has in the case of a number of carriers recently computed estimates of the cost of reproduction new and cost of reproduction less depreciation of their properties as of December 31, 1934, together with estimates of the value of land, original cost to date and working capital. It is understood that it is the plan of the Commission to make similar estimates as of that same date for all carriers, as rapidly as conditions permit. These estimates are sent by the Commission to the interested carrier for its information and for check if desired.

It is recommended that this report be accepted as information.

Exhibit No. 1
December 10, 1935.

CIRCULAR COMMUNICATION TO CHAIRMEN OF VALUATION COMMITTEES

A review of methods used in compiling returns to Valuation Order No. 3 of the Interstate Commerce Commission has been undertaken by Sub-Committee E–1, Valuation, Committee XI, Records and Accounts of the American Railway Engineering Association, in co-operation with the valuation staff of the Finance, Accounting, Taxation and Valuation Department, Association of American Railroads. As a result of this review, certain information has been collected relative to shortcuts in the preparation of such returns which may, upon proper application, be authorized by the Bureau of Valuation in the case of individual carriers. This information is presented for the benefit of interested carriers. It is recognized that there are carriers who now follow or have already considered some or all of the practices set forth in this memorandum.

(1) Minor Items of Other Track Material

Many carriers are using the cwt. method for reporting Account 10 items on B.V. Form 588, which, experience has shown, is the easiest method for repricing purposes. Where this plan has not been adopted some advantage may be secured through reporting costs without units in respect to both the installation and retirement of sundry items of other track material, such as nut locks, bolts, guard rails, guard rail clamps, gage rods and switch stands. These items generally, comprise only a small fraction of 1% of a carrier's total property; but if units are reported, a very considerable amount of time is required therefor. Under the suggested plan the costs only would be collected into one group and shown on the 588's as "Sundry Items" without any segregation or detailed description of the individual items.

Furthermore, the items of frogs and switches may be reported without classification by each different length.

An illustration of the methods above mentioned is presented as follows:

Column 1	*Column 3*
Frogs, rigid, 90-lb.	Each
Frogs, rigid, hard center, 100-lb.	Each
Frogs, solid manganese, 105-lb.	Each
Switches, 100-lb.	Each
Sundry items, nut locks, bolts, guard rails, guard rail clamps and switch stands (Added costs $38,952.91—Retired; Cost of Reproduction New $8,127, Costs from V.O. No. 3, $4,302.55)	Lot

The column numbers shown in the foregoing refer to the columns of Form 588–R. The information to be inserted in the other columns of B.V. Form 588–R is, for purposes of brevity, omitted from the above illustration.

The costs shown in column 1 as above illustrated are of course to be included in the totals for Account 10 in columns 5, 11 or 12 as may be appropriate.

(2) Reduction in Number of Valuation Sections

For the past several years suggestions have been made by interested parties that in some cases a reduction in the number of valuation sections would be desirable. It is recognized that there are many instances where reductions are not feasible. However, consolidations of valuation sections for the 588 returns have been adopted by some carriers, after approval by the Bureau, and have been made without disturbing the system of valuation sections used in keeping the details underlying the 588 reports.

Attention is also called to the following practices which are approved by the Bureau of Valuation for general use and for which individual authority need not be obtained.

(3) Description of Property Retired

When practicable to do so, the entire description of property retired need not be shown on the 588 return; it is sufficient merely to identify the property by reference to the Engineering Report page, if the property was included in the basic inventory, or to the page of the 588 return, if the property was installed subsequent to valuation date.

(4) Building Types

Whenever buildings can be typed, the description to be reported on B.V. Form 588 is simplified thereby.

(5) Completion Reports as Sub-Schedules of 588 Returns

Completion Reports may be used as sub-schedules of the 588 returns in reporting property designated as "structural" in Supplement 5 to Valuation Order No. 3. When so used, the total charges and credits for the particular project or account are to be shown on the 588 return with appropriate reference to the completion report, a copy of which must accompany the return as a sub-schedule thereof. If the completion report includes property other than that to be covered by the sub-schedule, a copy of only that part of the completion report relative to the particular structure should be submitted. Furthermore, the sub-schedules applicable to any account should be placed in the return immediately after the 588–R sheets for that account.

(6) Carbon Back Copies of B. V. Form 588

Where it will result in a saving to the carrier, the Bureau of Valuation has granted permission to furnish two copies without carbon backing.

(7) Average Prices for Retirement of Track Material

Attention is also called to the following practice for estimating cost of property retired, which it is understood has been adopted by some carriers with beneficial results. Par. 6, on page 4, of Revised Supplement No. 5 to Valuation Order No. 3 provides:

> "In determining the cost of property retired from service when it is impracticable because of the relatively large number and small size of units of any kind to determine the specific cost thereof, average costs may be used."

The ascertainment of the actual cost of many kinds of track material, in tracks to be retired, is exceedingly laborious, and generally, even at best, can be accomplished only with approximate accuracy. The process of ascertaining the cost can be curtailed by the use of average prices, by items, established yearly, based upon the total quantities and costs of each of the various items of property, as of the time of the establishment. Under this method the average prices fluctuate from year to year and follow the yearly changes in quantities and costs.

(8) Suggested Form for Reporting Equipment Changes

Some carriers have adopted a system of records for keeping track of equipment changes which provides for a combination Completion Report, Record of Property Changes and B.V. Form 588 in one form, and they are using average prices for retiring equipment within an inventory group. Attention was called to this practice and a sample form was inserted in the 1935 report of Committee XI, and will be found on page 433 and 434 of the printed Proceedings of the AREA.

The work of the Committee will be continued and further advice sent you at a later date.

(Signed) E. H. Bunnell.

Appendix G

(F–1) CHANGES OR REVISIONS IN I.C.C. CLASSIFICATION OF ACCOUNTS

W. R. Kettenring, Chairman, Sub-Committee; Anton Anderson, A. M. Blanchard, W. F. Cummings, C. C. Haire, J. H. Hande, C. A. Knowles, Chas. Silliman.

The I.C.C. issued two orders during the year 1935 changing the provisions of the current Accounting Classifications. The order of most interest to railway engineers was issued under date of September 16, 1935 and dealt with the accounting for ballast.

The principal changes resulting from this order are:

(a) The establishment and definition of ballast sections and the requirement that a continuing record be maintained of ballast in place.

(b) The distribution to investment account of the expense of placing additional ballast.

(c) The classification of ballast in three major groups.

(d) The handling of ballast of a superior grade placed in lieu of ballast of an inferior grade as property retired and replaced.

It appears that the continuing ballast record required by the Order may be in either statement or graphic form. In some cases present records will be adaptable, but it is probable in the majority of cases new records will be required to meet the requirements of the Order. The preparation of these records can doubtless be deferred in many districts, pending application of additional ballast in such districts.

The change in the Accounting Classifications has the effect of charging to investment account the current cost of placing additional ballast which, under rules previously affected, would have been charged to operating expenses. It also eliminates accounting for ballast under the so-called "Betterment" method of accounting, and provides that the cost of ballast replaced by other ballast of superior grade shall be retired at its original cost, and the cost of the new ballast charged to investment account. This is an improvement, as it is difficult to properly represent the cost of any property where betterment accounting is involved.

It is proposed that the subject of ballast records be continued as a subject for later report.

The Order effective January 1, 1936 reads as follows:

"In the Matter of a Uniform System of Accounts to be kept by Steam Roads

At a Session of the INTERSTATE COMMERCE COMMISSION, Division 4, held at its office in Washington, D. C., on the 16th day of September, A. D., 1935.

In the matter of modifying the text of road-and-equipment account 11, "Ballast," and operating-expense account 218, "Ballast."

IT IS ORDERED, That the text of account 11, "Ballast," be and it is hereby modified to read as follows:

> 11. BALLAST.—(A) This account shall include the cost (including the cost of transportation, of work-train service, and of unloading the material) of ballast applied in constructing or increasing the ballast section in all tracks (both temporary and permanent) used for transportation service (including shop, fuel-station, supply-yard, wood-preserving plant, and equipment-storage tracks) except that when ballast material placed creates a ballast section in excess of the section established by the carrier, or authorized by the Commission, if over 30 inches (see paragraph (D)), a quantity of ballast equal to such excess quantity applied shall be considered as retired and accounted for in accordance with paragraph (C) of account 218, "Ballast."
>
> (B) When a different kind or grade of ballast material is applied in replacement and the ballast applied is more or less durable than that replaced, the cost of the new ballast material applied shall be charged to this account and the cost (estimated if not known) of an equal quantity of ballast material replaced shall be credited to this account and charged to operating expense account 218, "Ballast." For the purpose of accounting under this paragraph, ballast material shall be considered as classified in the following groups, viz., Group 1, Crushed stone, washed gravel, crushed gravel, crushed slag, (not granulated); Group 2, Screened gravel, disintegrated granite, pit or bank run gravel, bank slag, chats, burnt clay; Group 3, Granulated slag, volcanic cinders, coal cinders, sand, mine waste, etc. and the replacement of ballast material included in one group of this classification by ballast material included in another group shall be accounted for in accordance with the provisions of this paragraph.
>
> (C) The carrier shall maintain a continuing record showing at all dates the established ballast sections of all tracks.
>
> (D) The term "ballast" means material which has been specially selected and transported for use in sustaining and holding the tracks in place. Material of the quality of that in the subgrade shall not be accounted for as ballast.
>
> (E) The term "ballast section" means the quantity of ballast measured by depth and width which has been placed by the carrier as the proper standard for the construction and maintenance of the tracks involved except that unless otherwise authorized by the Interstate Commerce Commission the ballast section shall be limited to a section 30 inches below the base of the rail. The carrier's applications to the Commission for special authority shall give full details of the reasons which in its opinion justify the establishing of ballast sections of unusual depth.
>
> (F) The term "established ballast section" means the ballast section which has been created at the nearest date prior to any given date. (See paragraph (E).)
>
> (G) The quantity of ballast submerged in grade revisions shall be considered as retired and accounted for in accordance with paragraph (C) of the text of account 218, "Ballast."
>
> NOTE A.—The cost of placing ballast in tracks not previously ballasted and of applying ballast to increase the ballast section shall be charged to account 12, "Track laying and surfacing." The cost of applying ballast to maintain the established ballast section and of preparing tracks which have been used in operation for the reception of ballast, shall be charged to account 220, "Track laying and surfacing."
>
> NOTE B.—The cost of material other than ballast placed to form a crown in the middle of the tracks over the ties shall be charged to account 3, "Grading."
>
> NOTE C.—The cost of ballast material placed on decking of bridges, solely for fire protection shall be included in account 6, "Bridges, trestles, and culverts."

Note D.—When cinders, accumulated by the carrier, are used as ballast the cost of loading at ash pits or power plants shall be charged to appropriate expense accounts and only the cost of transporting and unloading shall be charged to this account. The cost of placing cinders in tracks shall be charged to account 12, "Track laying and surfacing," or account 220, "Track laying and surfacing." (See note A to this account.) No charge shall be made for the value of the cinders.

Note E.—The cost of constructing tracks used solely for the treatment of timber at timber-treating plants shall be included in the cost of the facilities with which they are associated. The cost of tracks used for delivering timber to or hauling treated timber from timber-treating plants shall be appropriately included in this account and in accounts 3, "Grading," 8, "Ties," 9, "Rails," 10, "Other track material," and 12, "Track laying and surfacing."

Note F.—To the extent that it has been definitely determined, in connection with the retirement and replacement of ballast and the placing of ballast to maintain the established ballast section, that the subsidence of ballast in the subgrade has increased the subgrade section, so much of the material as has definitely increased the subgrade section, at prices fairly representing the value thereof for grading purposes, shall be credited to account 218, "Ballast," and charged to account 3, "Grading."

It is Further Ordered, That the text of account 218, "Ballast," be and it is hereby modified to read as follows:

218. Ballast.—(A) This account shall include the cost of ballast (including the cost of work-train service and of unloading material) used for maintaining the established ballast section in all tracks used in transportation service including shop, fuel-station, supply-yard, wood-preserving plant, and equipment-storage tracks. (For definition of the terms "ballast" and "ballast section" see sections (D) and (E) of the text of account 11, "Ballast.")

(B) To this account shall also be charged the cost (estimated if not known) of ballast replaced with a different kind or grade of ballast material applied. (See paragraph (B) of the text of account 11, "Ballast.")

(C) The book cost of quantities of ballast equal to the quantity of ballast applied in excess of a ballast section of 30 inches or the ballast section authorized by the Commission (if over 30 inches) (note paragraph (A) of the text of account 11, "Ballast") and the quantities of ballast submerged in grade revision projects shall be accounted as retired (note paragraph (G) of account 11, "Ballast") and shall be charged to this account. This account shall be credited and account 3, "Grading," shall be charged with the value of the quantity of such material, which it has definitely been determined has increased the subgrade section, at prices fairly representing the value thereof for grading purposes.

Note A.—The cost of applying ballast to maintain the ballast section shall be charged to account 220, "Track laying and surfacing."

Note B.—The cost of placing earth to restore a crown in the middle of the track over the ties shall be charged to account 220, "Track laying and surfacing."

Note C.—When cinders accumulated by the carrier are used for maintaining the ballast section the cost of loading at ash pits or power plants shall be charged to account 388, "Enginehouse expenses—Yard," account 400, "Enginehouse expenses—Train," or to power-plant operation account and only the charge for work-train service and for unloading shall be included in this account. The cost of placing cinders in the track for restoring the ballast section thereof shall be charged to account 220, "Track laying and surfacing." No charge shall be made for the value of the cinders.

It is Further Ordered, That this order shall become effective on January 1, 1936. By the Commission, Division 4."

The previous Order of the Commission, dated May 28, 1935, effective June 1, 1935, prescribed a more elaborate form of income statement than that shown in the Classification previously effective.

A copy of this Order is not inserted, as it is thought those particularly interested in the subject can secure copies of same.

REPORT OF COMMITTEE VIII—MASONRY

MEYER HIRSCHTHAL, *Chairman;*
F. E. BATES,
G. E. BOYD,
KENNERLY BRYAN, JR.
M. F. CLEMENTS,
MAURICE COBURN,
T. L. CONDRON,
HARDY CROSS,
G. H. DAYETT,
THEO. DOLL,
G. F. EBERLY,
W. K. HATT,
A. C. IRWIN,
A. R. KETTERSON,
R. H. KUGLER,
J. A. LAHMER,
A. N. LAIRD,
O. V. PARSONS,
R. V. PROCTOR,
I. L. PYLE,
W. M. RAY,
F. M. ROBINS,
GEO. E. ROBINSON,
D. B. RUSH,
F. E. SCHALL,
C. P. SCHANTZ,
J. F. LEONARD, *Vice-Chairman;*
H. F. SCHRYVER,
Z. H. SIKES,
L. W. SKOV,
G. R. SMILEY,
A. W. SMITH,
H. H. TEMPLE,
J. H. TITUS,
JAMISON VAWTER,
L. W. WALTER,
C. A. WHIPPLE,
J. J. YATES,
Committee.

To the American Railway Engineering Association:

Your Committee on Masonry respectfully presents reports on the following assigned subjects:

(1) Revision of Manual (Appendix A).

(2) Specifications and Principles of Design of Plain and Reinforced Concrete and Brick for Use in Railway Bridges, Buildings and Culverts, collaborating with Committees I—Roadway, VI—Buildings, VII—Wood Bridges and Trestles, XIII—Water Service, Fire Protection and Sanitation, and XV—Iron and Steel Structures (Appendix B). Partially complete, with recommended conclusions for publication in the Manual.

(3) Progress in the Science and Art of Concrete Manufacture (Appendix C). Partially complete, with recommended conclusions for publication in the Manual.

(4) Contact with Joint Committee on Standard Specifications for Concrete and Reinforced Concrete. Progress report.

(5) Specifications for Foundations, including Excavation, Cofferdam, Piling, etc. (Appendix D). Partially complete, with recommended conclusions for publication in Manual.

(6) Methods and Practices of Lining and Relining Tunnels, collaborating with Committees I—Roadway (Appendix E). Partially complete, with recommended conclusions for publication in the Manual.

(7) Specifications for Placement of Concrete by Pumping. Progress report.

(8) Design of Expansion Joints involving Masonry Structures, collaborating with Committee XV—Iron and Steel Structures and with Special Committee on Waterproofing of Railway Structures (Appendix F). Progress report.

(9) Review Specifications for Overhead Highway Bridges of the Association of State Highway Officials insofar as they relate to masonry (Appendix G). Progress report.

THE COMMITTEE ON MASONRY,
M. HIRSCHTHAL, *Chairman.*

Bulletin 384, February, 1936.

Appendix A

(1) REVISION OF MANUAL

J. F. Leonard, Chairman, Sub-Committee; G. F. Eberly, J. A. Lahmer, A. N. Laird, D. B. Rush, L. W. Walter, C. A. Whipple, J. J. Yates.

SPECIFICATIONS FOR PORTLAND CEMENT CONCRETE, PLAIN AND REINFORCED—1931

Revise Article 10 of Section I, Materials to read:

"Steel bars or rods used for reinforcement shall conform to the requirements of ASTM A–15–35 for billet steel concrete reinforcement bars and of intermediate grade unless otherwise called for on the plans.

"Structural steel shapes used for reinforcement shall conform to the requirements of the American Railway Engineering Association specifications for steel for the corresponding type of structure.

"Reinforcement shall be stored in racks in such a manner as to avoid contact with the ground."

Article 22 of Section II, Proportioning and Mixing, page 570, shall refer to the new ASTM Specification C–31–33 and C–39–33.

Specifications for Billet Steel Concrete Reinforcement Bars—1920, pages 633–636 shall be changed to refer to ASTM A–15–35.

Specifications for Reinforced Concrete Culvert Pipe, Article 141 to Article 177, and pages 601 to 613, to be deleted and replaced by proper reference to ASTM Specification C–76–35T.

Article 4 of Section I page 567 should now refer to ASTM C–40–33, Test for Original Impurities in Sand.

Article 13, page 568, Wire, shall be amplified to refer to ASTM Specification A–82–33.

Appendix B

(2) SPECIFICATIONS AND PRINCIPLES OF DESIGN OF PLAIN AND REINFORCED CONCRETE

A. N. Laird, Chairman, Sub-Committee; F. E. Bates, Hardy Cross, G. H. Dayett, Theo. Doll, A. C. Irwin, A. R. Ketterson, J. F. Leonard, C. P. Schantz, Z. H. Sikes, L. W. Skov, A. W. Smith, Jamison Vawter, C. C. Williams.

SECTION I—REINFORCED CONCRETE TRESTLES

The Committee submits on attached insert detail plans for reinforced concrete railroad trestles with three pile bents, designed for Cooper's E–72 loading, and 24-inch precast reinforced concrete pile. The Committee recommends their adoption for printing in the Manual.

SECTION II—WIND LOAD STRESSES—COMPOSITE AND PIPE COLUMNS

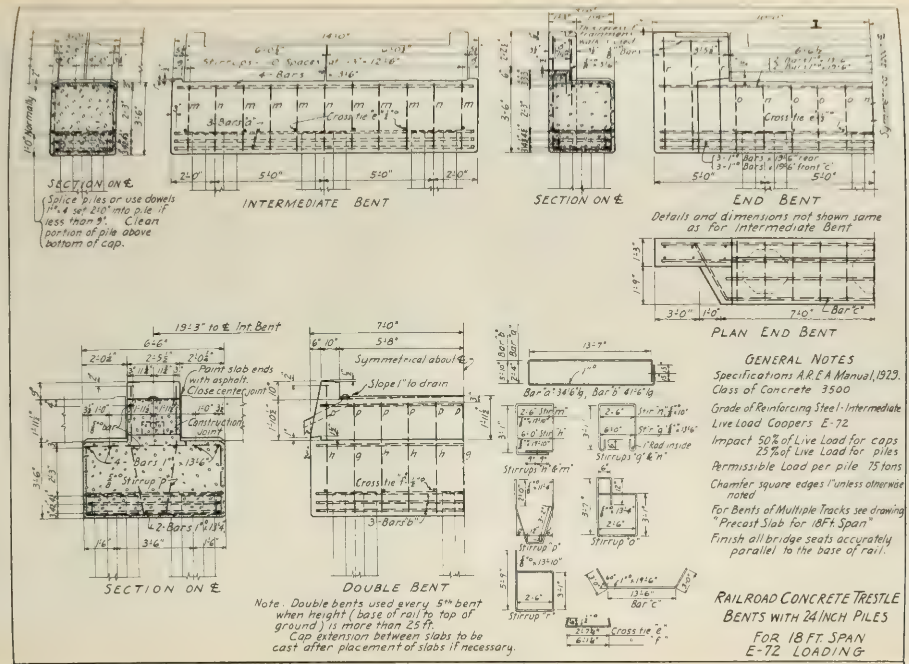
(a) Unit Stresses for Buildings When Wind Loads are Included

The Committee submits the following statement as information with the intention of offering it for adoption as standard practice at the next meeting of the Association:

"In the design of buildings when wind stresses are considered in combination with dead load and live load stresses, design unit stresses for concrete and for steel reinforcement may be increased by 33 1/3 per cent, provided, however, that normal design unit stresses shall not be exceeded for the combination of dead load and live load stresses only."

(b) Specifications for Composite Columns and Pipe Columns

The Committee submits the following specifications as information. It is the intention of the Committee to make such revisions therein as may be necessary during the

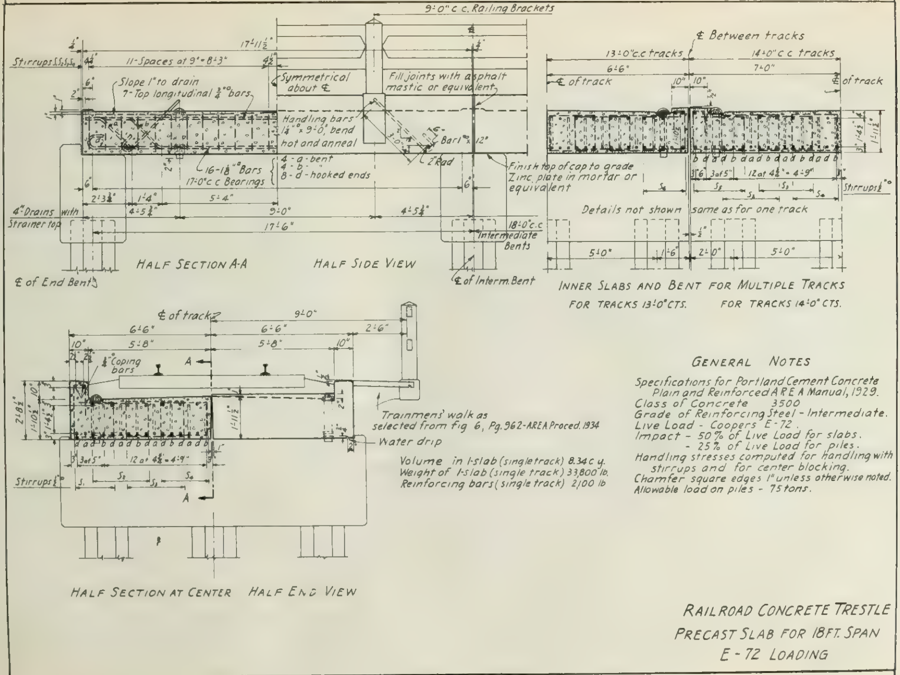

SECTION ON ℄
Splice piles or use dowels 1"° x set 2'0" into pile if less than 9'. Clean portion of pile above bottom of cap.
INTERMEDIATE BENT
SECTION ON ℄
END BENT
Details and dimensions not shown same as for Intermediate Bent
PLAN END BENT
SECTION ON ℄
Paint slab ends with asphalt. Close center joint
Construction joint
DOUBLE BENT
Symmetrical about ℄
Slope 1" to drain
Bar "a" 34'6" lg, Bar "b" 41'6" lg
Stirrups "n" & "m"
Stirrups "g" & "h"
Stirrup "p"
Stirrup "o"
Stirrup "r"
Bar "c"
Cross tie "e" "f"

Note. Double bents used every 5th bent when height (base of rail to top of ground) is more than 25 ft. Cap extension between slabs to be cast after placement of slabs if necessary.

GENERAL NOTES

Specifications A.R.E.A Manual, 1929.
Class of Concrete 3500
Grade of Reinforcing Steel - Intermediate
Live Load Coopers E-72
Impact 50% of Live Load for caps
25% of Live Load for piles
Permissible Load per pile 75 tons
Chamfer square edges 1" unless otherwise noted
For Bents of Multiple Tracks see drawing "Precast Slab for 18 Ft. Span"
Finish all bridge seats accurately parallel to the base of rail.

RAILROAD CONCRETE TRESTLE BENTS WITH 24 INCH PILES FOR 18 FT. SPAN E-72 LOADING

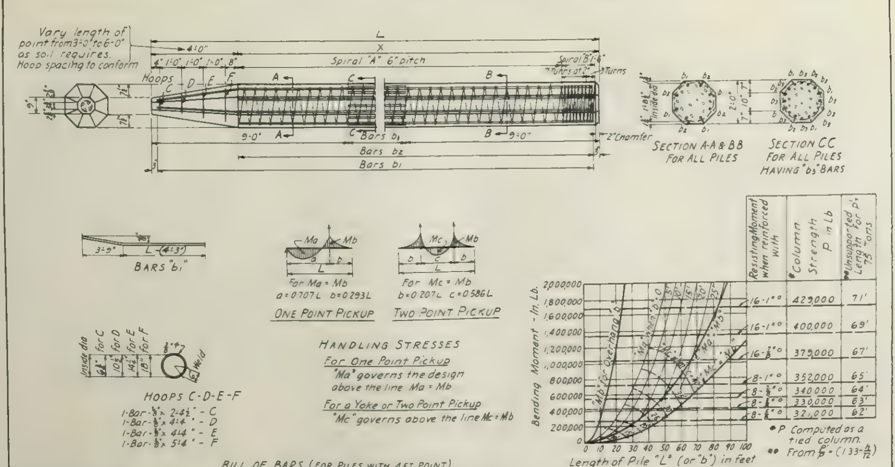

9'0" c.c. Railing Brackets
Stirrups
11-Spaces at 9" = 8'3"
Slope 1" to drain
7-Top longitudinal ¾"° bars
Symmetrical about ℄
Fill joints with asphalt mastic or equivalent
Handling bars 1¼"° x 9'0", bend hot and anneal
16-1⅛" Bars 17'0" c.c. Bearings
4-a-bent
4-b-
8-d-hooked ends
Finish top of cap to grade. Zinc plate in mortar or equivalent
4" Drains with Strainer top
℄ of End Bent
HALF SECTION A-A
HALF SIDE VIEW
18'0" c.c. Intermediate Bents
℄ of Interm. Bent
℄ Between tracks
13'0" c.c. tracks
14'0" c.c. tracks
℄ of track
Details not shown same as for one track
INNER SLABS AND BENT FOR MULTIPLE TRACKS
FOR TRACKS 13'0" CTS.
FOR TRACKS 14'0" CTS.
℄ of track
Coping bars
Trainmens' walk as selected from fig 6, Pg. 962-AREA Proced. 1934
Water drip
HALF SECTION AT CENTER
HALF END VIEW

Volume in 1-slab (single track) 8.34 c.y.
Weight of 1-slab (single track) 33,800 lb.
Reinforcing bars (single track) 2100 lb

GENERAL NOTES

Specifications for Portland Cement Concrete Plain and Reinforced A.R.E.A Manual, 1929.
Class of Concrete 3500
Grade of Reinforcing Steel - Intermediate.
Live Load - Coopers E-72.
Impact - 50% of Live Load for slabs.
- 25% of Live Load for piles.
Handling stresses computed for handling with stirrups and for center blocking.
Chamfer square edges 1" unless otherwise noted.
Allowable load on piles - 75 tons.

RAILROAD CONCRETE TRESTLE PRECAST SLAB FOR 18FT. SPAN E-72 LOADING


Vary length of point from 3'0" to 6'0" as soil requires. Hoop spacing to conform
Hoops
Spiral "A" 6" pitch
Spiral "B"
2" Chamfer
Bars b1
Bars b2
Bars b1
SECTION A-A & BB FOR ALL PILES
SECTION CC FOR ALL PILES HAVING "b3" BARS
BARS "b1"
HOOPS C-D-E-F
Inside dia
For C
For D
For E
For F
Weld
ONE POINT PICKUP
For Ma = Mb a=0.707L b=0.293L
TWO POINT PICKUP
For Mc = Mb b=0.207L c=0.586L
Bending Moment - In. Lb.
Length of Pile "L" (or "b") in feet
"Mb" for Overhang "b"
"Ma" when "b" = 0
"Mc" = "Mb"
"Ma" = "Mb"

1-Bar-⅜" x 2'4½" - C
1-Bar-⅜" x 4'4" - D
1-Bar-⅜" x 4'4" - E
1-Bar-⅜" x 5'4" - F

HANDLING STRESSES

For One Point Pickup
"Ma" governs the design above the line Ma = Mb
For a Yoke or Two Point Pickup
"Mc" governs above the line Mc = Mb

Resisting Moment when reinforced with	*Column Strength P in Lb	**Unsupported Length for P = 75 tons
16-1"°	429,000	71'
16-1"°	400,000	69'
16-⅞"°	379,000	67'
8-1"°	352,000	65'
8-⅞"°	340,000	64'
8-¾"°	330,000	63'
8-⅝"°	321,000	62'

* P Computed as a tied column.
** From $\frac{P'}{P} = (1.33 - \frac{h}{72})$

REINFORCEMENT REQUIRED FOR HANDLING

Cross Section	477 sq in.
Perimeter	79 in
Core diameter	21 in
Core area	346 sq in
Concrete in 4ft point	0.248 c.y.
Concrete in "X" per ft	0.123 c.y.
Weight of point (4ft)	1000 Lb
Weight of "X" per ft.	498 Lb

GENERAL NOTES

Specifications from A.R.E.A Manual, 1929.
Class of concrete 3500
Permissible pile load P' = 75 tons

BILL OF BARS (FOR PILES WITH 4FT POINT)

Length L	Straight X	LONGITUDINALS								SPIRALS						HOOPS				Vol of Pile C.Y.	Wt of Pile Lb
		b1 (bent)			b2		b3		Wt in Lb		A			B		C	D	E	F		
		Size	No	Length	No	Length	No	Length		No 4 W re (BW6) 2-1" Spacer B Finish ends with 1½ flat turns	No	No. of Turns	Wt Lb	No	Wt Lb						
20'	16'	⅞"°	4	19'6"	4	15'9"			147		One	29	48	One	10	One (Wt. 9 Lb)	One (Wt. 13 Lb)	One (Wt. 16 Lb)	One (Wt. 20 Lb)	2.72	9000
25'	21'	⅞"°	4	24'6"	4	20'9"			189			39	64							2.83	11900
30'	26'	⅞"°	4	29'6"	4	25'9"			232			49	80							3.45	14000
35'	31'	⅞"°	4	34'6"	4	30'9"			532			59	96							4.06	16500
40'	36'	⅞"°	4	39'6"	4	35'9"	8	22'0"	975			69	112							4.68	18900
45'	41'	⅞"°	4	44'6"	4	40'9"	8	27'0"	1140			79	128							5.29	21400
50'	46'	1"°	4	49'6"	4	45'9"	8	32'0"	1700			89	144							5.91	24000
55'	51'	1"°	4	54'6"	4	50'9"	8	37'0"	1910		Two	49	160							6.52	26400
60	56'	1"°	4	59'6"	4	55'9"	8	42'0"	2125			54	178							7.14	28900

24" REINFORCED CONCRETE OCTAGONAL PILE

coming year and to present them next year for publication in the Manual as recommended practice.

SPECIFICATIONS FOR DESIGN OF COMPOSITE COLUMNS AND PIPE COLUMNS

(A) COMPOSITE COLUMNS

Permissible Load

1. The permissible load on a composite column consisting of a structural steel or cast iron column thoroughly encased in concrete reinforced with both longitudinal and spiral reinforcement, shall not exceed that given by Formula (1).

$$P = 0.25\,A_c f'_c + f_s A_s + f_r A_r \quad \ldots\ldots (1)$$

Wherein A_c = net area of concrete section = $A_g - A_s - A_r$.

A_s = cross-sectional area of longitudinal bar reinforcement.

A_g = gross area.

A_r = cross-sectional area of the steel or cast iron core.

f_r = permissible unit stress in metal core, not to exceed 16,000 p.s.i. for the steel core; or 10,000 p.s.i. for a cast iron core.

f^1_c = compressive strength of the concrete, as found by tests of standard 6 by 12-in. control cylinders, as prescribed in Article 22.

f_s = nominal working stress in vertical column reinforcement, to be taken at 45 per cent of the minimum specification value of the yield point, viz; 18,000 p.s.i. for intermediate grade steel and 22,500 p.s.i. for hard grade steel.

Details of Metal Core and Reinforcement

2. The cross-sectional area of the metal core shall not exceed 20 per cent of the gross area of the column. If a hollow metal core is used it shall be filled with concrete. The amounts of longitudinal and spiral reinforcement and the requirements as to spacing of bars, details of splices and thickness of protective shell outside the spiral shall conform to the limiting values specified for Spiral Columns (Article 123 of Manual). A clearance of at least 3 in. shall be maintained between the spiral and the metal core at all points except that when the core consists of a structural steel H-column, the minimum clearance may be reduced to 2 inches.

Splices and Connections

3. Metal cores in composite columns shall be accurately milled at splices and positive provision shall be made for alinement of one core above another. Transfer of loads to the metal core shall be provided by the use of bearing members such as billets, brackets or other positive connections. These shall be provided at the top of the metal core and at intermediate floor levels where required. Ample section of concrete and continuity of reinforcement shall be provided at the junction with beams or girders. At the column base, the provision shall be made to transfer the load to the footing at safe unit stresses in accordance with provisions for transfer of stress at the base of columns (Article 151 of Manual). The base of the metal core shall be designed to transfer the load from the entire composite column to the footing or it may be designed to transfer the load from the metal core only, provided the base is so placed in the pier or pedestal as to leave ample section of concrete above it for the transfer of load from the reinforced concrete section of the column by means of bond on the vertical reinforcement and by direct compression on the concrete. The column as a whole shall satisfy the requirements of Formula (1) at any point. In addition to this, the reinforced concrete portion shall be designed to carry all floor loads brought on to the column at levels between the metal

brackets or connections in accordance with Formula 36 (Article 123). In applying this formula to a hollow core filled with concrete, the area within the metal core shall not be included.

Permissible Load on Metal Core

4. The metal core of composite columns shall be designed to carry safely any construction or other loads placed upon them prior to their encasement in concrete.

(B) PIPE COLUMNS

Permissible Load

5. The permissible load on columns consisting of steel pipe filled with concrete shall not exceed that given by Formula (2).

$$P = 0.25\, f'_c A_c + f'_r A_r \quad \text{(2)}$$

The value of f'_r shall be given by Formula (3) but shall not exceed four-tenths of the yield point stress of a pipe having the same section and length as that used.

$$f'_r = 18{,}000 - 70\,\frac{h}{r} \quad \text{(3)}$$

Wherein f'_r = average unit stress in metal pipe.
h = unsupported length of column.
r = least radius of gyration of steel pipe section.

In the absence of tests to determine the yield point of the pipe, the value of f'_r shall be taken as 8,000 p.s.i. For long columns, in which the value of $\frac{h}{r}$ exceeds 28.5, the value of f'_r shall be found by multiplying the value from Formula (3) by the factor $\frac{\text{Yield Point of Pipe}}{40{,}000}$. If the yield point is not known, the factor shall be taken as 0.5.

SECTION III—RIGID FRAME BRIDGES

The Committee submits the following specifications as information. It is the intention of the Committee to make such revisions as may be necessary after consideration of criticisms and suggestions received, and to present them next year for publication in the Manual as recommended practice.

RECOMMENDATIONS FOR THE DESIGN IN REINFORCED CONCRETE OF RIGID-FRAME BRIDGES WITHOUT SKEW

(A) BRIDGES OF ONE SPAN

(I) Definition and Types

1. Definition.—The term rigid-frame bridge is here used to mean a bridge in which the deck is structurally integral with approximately vertical abutments.
2. Types.—Rigid-frame bridges may be built either as slab bridges or as ribbed bridges, and may have either curved or flat soffits. In the slab bridge the deck structure is solid. In the ribbed bridge the deck structure consists of ribs or girders supporting a deck slab; the soffit of the rib may be reinforced near the abutments by a transverse slab.*

(II) Design

1. Loads and Deformations to be Considered in Design.—In the design of rigid-frame bridges the following loads and deformations shall be considered:
    - (a) Dead load.
    - (b) Live load of the intensity and distribution specified for highway or railway bridges by the American Railway Engineering Association.

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* For moderate spans up to 50 feet the slab type will usually prove more economical; it should be considered in any case.

(c) Impact as specified by the American Railway Engineering Association.
(d) Active earth pressure against the abutments including the effect of surcharge.
(e) Deformations produced by changes of temperature of ± 40° Fahr. assuming a coefficient of expansion of 0.000006.
(f) Distortions from volume changes in setting equivalent to a drop in temperature of 30° Fahr., unless methods of construction are to be used which eliminate or reduce this effect.
(g) Horizontal spread of footings varying from zero to ½ inch at each footing depending on the characteristics of the foundation and the horizontal pressures used in designing the footings.
(h) Tractive, wind and centrifugal forces are rarely, if ever, important in the design of rigid-frame bridges. Where the stresses produced by these causes are sufficient to affect the design, their effect shall be included.

2. Preliminary Design.—A closely approximate design of all sections except those near the center of the deck and near the tops of the footings may be made by assuming the structure to act as an arch having hinges at the center and near the top of each footing.

Preliminary design of sections near the center may be made on the assumption that the deck acts as a beam fixed at ends.

3. Assumptions in Design.—The following assumptions shall be made in the design of the structure:

(a) For the purpose of computing bending moments, the moments of inertia of any section shall be assumed to be that of the uncracked section taken entirely across the bridge, including only the structural elements. The effect of reinforcement may be either included or neglected.
(b) In computing moments and forces produced by distortions due to shrinkage or to change of temperature and by movements of the footings, the value of E shall be assumed as 3,000,000 lb. per sq. in.
(c) In computing internal stresses the value of the modular ratio n shall be assumed as specified by the American Railway Engineering Association.

The following additional assumptions may be made in the design of the structure:

(d) The axes of all members are straight, the axis of the deck passing through the center of the mid-section of the deck and the axis of each abutment connecting the centers of sections of the abutment just above the footing and just below the deck.
(e) Longitudinal movement of the deck as a whole is restrained.

4. Critical Combinations of Loads and Distortions.—The following combinations of loads and distortions will determine the design at critical sections, using permissible stresses specified below:

(a) Sections near the center of the deck
    1. Dead load, live load, impact.
    2. Dead load, live load, impact, drop in temperature, shrinkage.
    3. Dead load, live load, impact, drop in temperature, shrinkage, spread of footings.
(b) Sections near the knee
    1. Dead load, live load, impact, earth pressure
    2. Dead load, live load, impact, earth pressure, rise in temperature.
(c) Footings
    Dead load, live load, impact, rise in temperature.

5. Methods of Analysis.—Shears, bending moments and reactions shall be determined in accordance with the above assumptions by the theory of elasticity.

Internal stresses shall be computed by the theory of flexure as commonly applied to sections of reinforced concrete.

6. Formulas for Analysis.—

(a) Deck assumed straight. Longitudinal movement of deck restrained.

If, in the analysis, it is assumed that the axes of the members are straight and that longitudinal displacement of the deck is prevented, the moments, and from these the shears and reactions, may be determined by either the general method of slope-deflection or by the method of moment distribution.

The elastic constants required in the analysis may be computed by use of the formulas below. (Consistent signs for the distances involved must be used throughout.) In any member (deck or abutment)

Let Δ be the length of a short segment of the axis, the moment of inertia of which is I. (If hinges exist at the footing the value $\frac{\Delta}{I}$ for such hinges is to be taken as infinity.)

x be the distance to the mid-point of this segment.

$\bar{x}$ be the distance to the end of the member, subscripts denoting the end under consideration.

The distance x and $\bar{x}$ are to be measured from the elastic centroid, determined so that

$$\Sigma \frac{\Delta}{I} x = 0$$

End moments due to rotation of one end without movement of the other end

$$E \left[\frac{1}{\Sigma \frac{\Delta}{I}} + \frac{\bar{x}_a^2}{\Sigma \bar{x}^2 \frac{\Delta}{I}} \right] \text{ at the end } A \text{ which is rotated}$$

$$E \left[\frac{I}{\Sigma \frac{\Delta}{I}} + \frac{x_a \; x_b}{\Sigma x^2 \frac{\Delta}{I}} \right] \text{ at the end } B \text{ held fixed.}$$

End moment due to unit relative transverse displacement of ends without rotation.

$$E \left[\frac{\bar{x}}{\Sigma x^2 \frac{\Delta}{I}} \right] \text{ where } \bar{x} \text{ is measured to the respective end under consideration.}$$

Fixed-end moment due to unit concentrated load.

$$\frac{\Sigma (x - e) \frac{\Delta}{I}}{\Sigma \frac{\Delta}{I}} + \frac{\Sigma (x - e)\, x \frac{\Delta}{I}}{\Sigma x^2 \frac{\Delta}{I}}$$

Where "e" is the distance from the elastic centroid to the load, the summations in the numerator to be taken from the load to the end of the member opposite to that under consideration. (This moment corresponds to compression on the soffit of the deck for vertical loads and on the back of the abutment for earth pressures.)

The effect of traction may be computed by assuming any convenient longitudinal movement of the deck, computing the longitudinal force producing it and finding by proportion the moments produced by the longitudinal traction.

(b) Deck assumed curved. Free longitudinal movement of the deck.

If, in the analysis, it is desired to include the effect of the curvature of the axis of the deck and to assume freedom of longitudinal displacement of the deck, the bending moments may be determined from the formulas below, and from the moments, shears and reactions may be determined:

In these formulas the terms "Δ" and "I" have the same meaning as above.

x is the horizontal distance of any section from a vertical axis so located that $\Sigma x \frac{\Delta}{I} = 0$.

y is the vertical distance of any section from a horizontal axis so located that $\Sigma y \frac{\Delta}{I} = 0$. x_1 and y_1 are coordinates of the center of any section at which the bending moment is desired.

M_o is the bending moment computed at any section on the assumption that the structure acts as a three-hinged arch with hinges at the centers of sections taken at the top of each footing and at the center of the mid-section of the deck.

Mi is the correction to be computed for M_o so that correct moment $= M_o - Mi$.

In applying these formulas consistent signs must be used throughout. Distances should be taken as positive when measured to the right or upward from the centroidal axes, bending moments as positive when they produce tension on the soffit of the deck or the face of the abutment. Expansions of the deck and inward movement of the abutments are to be taken as positive.

For Symmetrical Structures

Effect of Loads

$$Mi = \frac{\Sigma M_o \frac{\Delta}{I}}{\Sigma \frac{\Delta}{I}} + \frac{\Sigma M_o x \frac{\Delta}{I}}{\Sigma x^2 \frac{\Delta}{I}} x_1 + \frac{\Sigma M_o y \frac{\Delta}{I}}{\Sigma y^2 \frac{\Delta}{I}} y_1$$

Effect of Distortions

$$Mi = E \frac{y}{\Sigma y^2 \frac{\Delta}{I}} \text{ for unit longitudinal distortion.}$$

For Unsymmetrical Structures

Effect of Loads

$$Mi = \frac{\Sigma M_o \frac{\Delta}{I}}{\Sigma \frac{\Delta}{I}} + \frac{\Sigma M_o x \frac{\Delta}{I} - \frac{\Sigma xy \frac{\Delta}{I}}{\Sigma y^2 \frac{\Delta}{I}} \Sigma M_o y \frac{\Delta}{I}}{\Sigma x^2 \frac{\Delta}{I} - \frac{\left(\Sigma xy \frac{\Delta}{I}\right)^2}{\Sigma y^2 \frac{\Delta}{I}}} x_1$$

$$+ \frac{\Sigma M_o y \frac{\Delta}{I} - \frac{\Sigma xy \frac{\Delta}{I}}{\Sigma x^2 \frac{\Delta}{I}} \Sigma M_o x \frac{\Delta}{I}}{\Sigma y^2 \frac{\Delta}{I} - \frac{\left(\Sigma xy \frac{\Delta}{I}\right)^2}{\Sigma x^2 \frac{\Delta}{I}}} y_1$$

Effect of Distortions

$$Mi = E \frac{y_1 - x_1 \frac{\Sigma xy \frac{\Delta}{I}}{\Sigma x^2 \frac{\Delta}{I}}}{\Sigma y^2 \frac{\Delta}{I} - \frac{\left(\Sigma xy \frac{\Delta}{I}\right)^2}{\Sigma x^2 \frac{\Delta}{I}}} \text{ for unit longitudinal distortion*.}$$

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* This expression neglects any relative vertical movement of the footings which may occur or any relative vertical movement that would occur if the structure were free to expand. This effect is negligible in this type of structure.

7. Unit Stresses.—Stresses permitted in design for various combinations of dead, live load and impact shall conform to those specified by AREA, except that the permissible stress in concrete in compression shall not exceed $0.35 f'_c$.

   For combinations of stresses due to dead and live load with those due to change of temperature and/or shrinkage an increase of 25 per cent in working stresses shall be permitted.

   For combinations of stresses enumerated above with those due to movement of footings an increase of 33 per cent in working stresses shall be permitted.

(III) Details of Design

1. Transverse Distributing Bars.—Transverse distributing bars shall be provided in the deck as required in deck slabs of other concrete bridges.
2. Radius of Bend at Knee.—The radius of bend of the tension reinforcement at the knee should be made as large as possible consistent with the concrete dimensions.
3. Wingwalls.—Wingwalls should preferably be designed separately from the frame as ordinary retaining walls. The expansion joint between the abutment of the rigid frame and the wingwall should be provided with an adequate water stop.
4. Articulations at Footings.—Effective provision for tilting of the abutment due to changes in length of the deck may be secured either by flexure of the abutment near the top of the footing, by definite mechanical articulation and often to a considerable extent by rotation of the footing slab due to eccentric foundation pressure. Unless a definite hinge is provided, analyses for stresses near the top of the footing should be made on the assumption that the base of the footing is fixed.
5. Footings.—The bearing areas of footings shall be proportioned so that the allowable pressures on the foundations shall not be exceeded and that any settlement shall be approximately uniform.

   In case horizontal movement as a result of the horizontal component of the thrust appears possible, the effect of such movement should be investigated. The footing shall be so designed that the resultant pressure shall preferably lie within the middle third of the base and as close to the center of the base as practicable.

   Insofar as practicable, the forces tending to produce sliding of the abutment shall be resisted, by direct bearing on the foundation. Where this is impracticable, the frictional resistance of the footing slab on the foundation and the bearing resistance of abutting undisturbed material against back of the footing may be considered as assisting the stability against sliding. Additional resistance may be provided, if required, by the construction of a key or drop wall extending below the footing slab, in direct contact with undisturbed foundation material.* Where permanent cofferdam construction encloses the foundation, this may be considered as increasing the lateral bearing area against undisturbed material for resistance to sliding. Where the foundation rests on permanent piling or caisson construction, the horizontal component of batter piles or caissons may be considered in determining the resistance to sliding.
6. Construction and Expansion Joints.—The requirements of the AREA Standard Specifications Sections 57 to 63 incl., covering construction joints and any necessary longitudinal expansion joints, shall be complied with.

   Construction joints required to transmit stress shall be keyed and reinforced across the joint.
7. Drainage.—Adequate drainage shall be provided. Normally horizontal surfaces exposed to moisture shall be sloped for drainage. Deck slabs shall be given a slope preferably ¼-inch per foot and not less than ⅛-inch per foot, if practicable, away from longitudinal expansion joints. A raised lip shall be constructed at such joints to prevent impounded water from overflowing into the

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* It is recommended that in such cases, not more than 50 per cent of the estimated frictional resistance between the footing slab and foundation together with not more than 50 per cent of the allowable foundation bearing pressure per square foot for equivalent material, be used in computing the resistance to sliding due to key or drop wall.

joint. Suitable ballast guards and flashing shall be provided at all deck drainage openings with leadout pipes to prevent water falling on surfaces of the structure. Weep holes or pipe drains shall be provided for drainage of backs of abutments to prevent impounding of the water. Pipe openings shall be provided through all transverse walls or other members which would interfere with the normal flow of water, in accordance with the drainage layout. Provision shall be made for ultimate disposal of the water in accordance with the local requirements of the site.

8. Waterproofing.—The deck surface shall be waterproofed using a membrane type of waterproofing and a protective covering in accordance with the standard specifications therefor of the AREA. Backs of abutments above the footing slab shall be damp-proofed. All construction joints exposed to water, or in contact with soil or filling materials, including ballast, shall be waterproofed with a membrane type of waterproofing as specified for deck construction and shall preferably have a sheet metal water stop of non-corrosive material equally embedded in both sides of the joint for the full length thereof. Suitable keyways shall be constructed at construction joints where the details will permit.

9. Longitudinal Expansion Joints.—Longitudinal expansion joints shall preferably be provided so that the width of any single frame shall not exceed about 30 feet. Such joints should completely separate the structural parts including the footings.

(IV) Construction

1. General.—The General Specifications for Plain and Reinforced Concrete of the AREA shall apply hereto insofar as consistent, subject to such modifications as provided herein, or by the detailed plans which shall be rigidly adhered to.

   The Contractor shall submit a detailed construction schedule for approval by the Engineer.

2. Centering.—The Contractor shall submit designs for the centering for approval by the Engineer. Centering shall be of rigid construction, with adequate foundation bearing area, piling or other suitable construction to sustain the dead load of the concrete while it is being placed, construction equipment, and other construction loads. It shall be braced in both longitudinal and transverse directions and shall be constructed with adequate devices for adjusting the shape of the soffit and for striking the centering gradually and uniformly after the concrete has cured sufficiently. Allowance shall be made in the form and elevation of the centering for the dead load deflection of the deck. When local conditions such as waterway, roadway, or other conditions demand that specific clearances be provided under the structure during construction, such as to require that a long span be used for centering, allowance shall be made when setting the forms for the deflection of such span due to its own dead load and to the dead weight of the wet concrete to be supported, and suitable means shall be provided for adjusting the forms to their proper contour. Centering shall not be struck or removed until the concrete has sufficiently cured to maintain its own weight and that of the spandrel construction.

3. Concreting Methods.—The deck shall preferably be cast in one operation, symmetrically from the center.

   Casting of the deck shall not be begun until the abutment concrete has in the opinion of the Engineer attained adequate strength.

4. Curbs, Parapets, and Handrails.—Curbs, parapets and handrails shall preferably be cast after the forms for the deck have been struck. They shall in all cases be thoroughly doweled to the deck.

SECTION IV—FLOOR CONSTRUCTION—REINFORCED BRICKWORK

The Committee reports progress on the following subjects and recommends that the assignment be continued.

(a) Specifications for Ribbed Floor Construction.

(b) Reinforced Brick Work.

(c) Economics of Light-weight Aggregates.

Appendix C

(3) PROGRESS IN THE SCIENCE AND ART OF CONCRETE MANUFACTURE—1935

L. W. Walter, Chairman, Sub-Committee; M. Coburn, T. L. Condron, L. V Haegert, W. K. Hatt, A. C. Irwin, R. H. Kugler, J. A. Lahmer, R. V. Proctor, W. M. Ray, F. B. Robins, D. B. Rush, H. F. Schryver, J. H. Titus.

SECTION 1

SPECIFICATIONS FOR CURING PORTLAND CEMENT CONCRETE

General

These specifications for Heat Curing and Wet Curing are based on requirements when normal Portland cements are used.

When moderate low-heat cements are used, the curing time herein specified shall be increased 25 per cent.

When high-early-strength Portland cement is used, the curing period shall be not less than one-third of that specified for normal Portland cement.

Heat Curing

Concrete, when deposited in massive structures, shall have a temperature of not less than 40° Fahr.

When deposited in structures less than 6 ft. in thickness the following table for temperatures will govern:

Temperature of Air	*Min. Temp. of Concrete When Placed*
Below 30° Fahr.	70° Fahr.
Between 30° and 45°	60° Fahr.
Above 45°	45° Fahr.

In freezing weather, or when there is likelihood of freezing temperatures, within the specified curing period, suitable and sufficient measures must be provided for maintaining all concrete surfaces at a temperature of not less than 50° Fahr. for a period of not less than 5 days after the concrete is placed when normal Portland cement is used, and not less than 48 hours when high-early-strength Portland cement is used.

The temperature of concrete surfaces shall be determined by thermometers placed against the surfaces of the concrete.

Provision shall be made in form construction to permit the removal of small sections of forms to accommodate the placing of thermometers against concrete surfaces at locations designated by the Engineer.

After thermometers are placed, the apertures in forms shall be covered in a way to closely simulate the protection afforded by the forms.

In determining the temperatures at angles and corners of a structure, thermometers should be placed not more than 8-in. from the angles and corners.

In determining temperatures of horizontal surfaces, thermometers shall rest upon the surface under the protection covering normal to section involved.

Temperature readings shall be taken and recorded at intervals to be designated by the Engineer, over the entire curing period specified, and the temperatures so recorded shall be interpreted as the temperature of the concrete surfaces where thermometers were placed.

When protection from cold is needed to insure meeting these specification requirements, all necessary materials for covering or housing must be delivered at the site of the work before concreting is started and must be effectively applied or installed, together with such added heat furnished as may be necessary without depending in any way upon the heat of hydration during the first 24 hours after concrete is placed when normal Portland cement is used, or the first 18 hours when high-early-strength Portland cement is used.

When heat is supplied by steam or salamanders, covering or housing of the structure shall be so placed as to permit free circulation of air above and around the concrete within the enclosure, but to the exclusion of air currents from without, excepting that where salamanders are used, sufficient ventilation shall be provided to carry off gases. Special care shall be exercised to exclude cold drafts from angles and corners and from all projecting reinforcing steel.

When salamanders are used water vessels must be placed over them, or other means provided to maintain a high humidity within enclosures.

Wet Curing

When not otherwise specified, all concrete surfaces when not protected by forms, must be kept constantly wet for a period of not less than 7 days after concrete is placed when normal Portland cement is used, and not less than 52 hours when high-early-strength Portland cement is used.

The wet curing period for all concrete which will be in contact with brine drip, sea water, salt spray, alkali or sulfate-bearing soils or waters, or similar destructive agents, shall be increased to 50 per cent more than the periods specified for normal exposures.

When wood forms are left in place during the curing period they shall be kept sufficiently damp at all times to prevent openings at the joints and drying of the concrete.

Inspection shall be made of all exposed surfaces at intervals as directed by the Engineer, and job records shall be kept indicating whether surfaces were wet at times of inspection, and if not wet, stating reasons why not wet.

When wet curing is impracticable, liquid surface applications to prevent or minimize evaporation may be used in lieu of wet curing only when approved by the Engineer.

SECTION 2

GROUTING

And its Application to Masonry

Grouting as applied to masonry is undertaken to strengthen or solidify a structure or the materials supporting it; to fill cavities and to prevent or stop the flow of water.

A grouting accomplishment approaching the ideal is one in which grout is made to go where needed and not elsewhere; one in which grout can be made to penetrate where water would go and when in place will set up with good bond into an impervious and durable mass with minimum shrinkage and with the degree of strength necessary in the particular circumstances, obtainable by the use of bituminous materials, neat cement, mortars of cement and sand or sand substitutes, with or without admixtures.

In some operations grout may travel a long distance, sometimes designedly and sometimes because it is not possible to control the flow to definite areas. In most cases the extent of flow is obscured from view and sometimes it is difficult to determine the degree of success of the undertaking. If the purpose is to stop the flow of water the degree of success can be observed. It is sometimes feasible to take cores from structures or from foundation strata supporting or surrounding them as in dam construction where grouting has been done to solidify foundations or to stop the flow of water under or around the dam. (See Engineering News–Record—Nov. 21, 1935—for description of grouting under Norris Dam.)

While the term grouting suggests the use of cement it may be well to consider that other materials have been used on sizeable jobs.

Grouting porous natural rock at the site of the Madden Reservoir for the Panama Canal was done with fine clay because of a loam coating in the rock crevices, which would have interfered with the bonding of cement.

Asphalt has been used for grouting. Work at the Wilson Dam was done by pumping asphalt through pipes equipped with wires to provide heat by electric current to keep the material warm.

While grouting is usually done under pressure, some structures are adapted to grouting by gravity. An example of this type may be a tunnel section with shallow covering where holes may be driven with well drills from the top surface and grout poured, to refusal, down the holes to fill in the cavities.

In grouting with cement or mortar, grout is usually handled through pumps or forced out of tanks by compressed air. For some work, pressure under 100 pounds obtainable by hand pump, is adequate. For some operations requiring high pressure, continuous pumping is necessary for best results. For other work intermittent charges are not objectionable. For working in rock strata, as around dams, pressure up to 600 pounds is not uncommon, although 50 pounds has been deemed sufficient in other cases. It is reported that 1000 pounds pressure was used at the Boulder Dam site. Some operations use up to 2500 pounds pressure with very thin grout.

For the average job, among the questions arising are the following:

(1) Who will do the work?

(2) What materials should be used, whether cement, cement sand mortar, or a special material?

(3) If cement or mortar is used what should be the fluidity?

(4) Shall a definite procedure be followed or shall it be a cut-and-try procedure?

(5) What equipment is necessary or best adapted to the work?

(1) It seems reasonable to assume that those who have specialized in grouting work and have a background of experience in dealing with grouting problems should be better able than others to do the work successfully and economically.

(2) At first thought it might seem a simple matter to decide as between cement grout and mortar grout but ofttimes this question requires careful consideration. It is obvious that for grouting small cracks where the use of cement ground to pass a 200-mesh sieve and screened to remove possible lumps before using is advocated, mortar would be out of the question. Similarly where large cavities such as may be encountered above an arch in a tunnel lining, mortar may be appropriate. Between the two extremes there is a zone of debatable ground and, where there is any doubt, mortar should not be used. Experience in trying to economize on cement by using a lean mixture has often given disappointing results. Sand and cement or sand substitutes and cement tend to segregate under flowing action. Sand mortar may be used for filling cavities but it may or may not secure waterproofing. When mortar is used, drilling of more holes is generally required as the material does not penetrate as well as cement grout. A finely ground material of specific gravity approaching the specific gravity of cement is the most desirable substitute for sand in mortar for grouting. Special proprietary preparations or compounds have been used.

Some grouting contractors both in this country and abroad, are convinced that under certain conditions they can improve effectiveness and economy by the use of certain chemicals. Claim is made that some are in themselves sufficient and that others have merit when used in advance of grouting or as admixtures. This applies particularly to the closing of small seams and pores when waterproofing is the objective.

(3) It is generally recognized that it requires more water per bag of cement to get the degree of fluidity necessary to inject the grout than is desired in the grout in place. For the average job from six to ten gallons of water per bag of cement is used. Where the grout is of cement and water the lower figure is sometimes reduced but when sand is added the upper figure is often exceeded. The desirable degree of fluidity of the grout will depend upon the size of the cracks or cavities, the distance of flow and the pressure used. There may be uncertainty as to the first two factors and the tendency is to use more water than would be warranted under known conditions. Under all conditions, attempt should be made to provide escape of the surplus water required to give the necessary fluidity for placing. It is usually desirable to pump water in as a lubricant before grouting. This should not be done if there is a likelihood of the water being trapped to the extent that it cannot be forced out with the pressure used in placing the grout. This may and often does necessitate the drilling of a series of holes in advance of the grouting operation at appropriate distances from where the grout is injected.

(4) If a masonry structure, particularly of stone, is in such condition that its strength or stability is in doubt because of insufficient bond or large voids with interconnecting passages, decision should be made definitely in advance as to the method of approach.

An impressive example of following a predetermined procedure, arrived at as a result of months of research, may be cited in the selection of material and the manner of using it in grouting the construction joints between the large concrete blocks in the construction of the Boulder Dam. The success of the undertaking in that type of construction is a valuable contribution to the art. By design the joints averaged .08 of an inch in thickness. Before grouting, the joints were washed with water and then grouted with cement grout, the cement all passing a 200 mesh sieve. A thin cement grout of about 100 per cent w/c ratio by volume (7½ gallons of water per sack of cement) was used first, followed by a thicker grout varying in w/c ratio from 70 per cent to 80 per cent. Joints were poured slowly to permit air and water to escape. Water rising to the top was drained off and the joints refilled. Thereafter 50-pound pressure was applied to force the surplus water out of the grout. When the joint was finally filled and the pressure held at 30 pounds for 20 minutes the operation was considered completed.

In contrast to the above examples of following definite predetermined procedure, many grouting problems cannot so well be visualized or the best methods be definitely determined in advance and consequently require cut-and-try methods.

(5) Choice of proper equipment often means the difference between success or partial success and failure and there is need for a definite understanding between the owner and the contractor before work is started as to equipment readily available for the work involved so that the choice of materials and methods for grouting need not be made of secondary importance.

Appendix D

(5) SPECIFICATIONS FOR FOUNDATIONS

D. B. Rush, Chairman, Sub-Committee; F. E. Bates, M. F. Clements, G. F. Eberly, A. D. Harvey, C. S. Johnson, O. V. Parsons, Z. H. Sikes, L. W. Skov, G. R. Smiley, Jamison Vawter, C. A. Whipple.

GENERAL SPECIFICATIONS FOR SUB-STRUCTURES OF RAILWAY STRUCTURES

(I) GENERAL

Scope

1. These specifications cover the design and construction of ordinary simple substructures of railway structures.

Definition

2. Substructure refers to that part of the structure which supports the superstructure and its loads.

(II) DESIGN

General

3. The design drawings shall be prepared in such detail as to indicate clearly all important elements of the construction, dimensions, spacing and size of reinforcing bars, construction joints, waterproofing, drainage and all foundation pressures.

Drawings

4. After the contract has been awarded and before any work is commenced, the Contractor shall submit to the Engineer for approval, duplicate prints of drawings which supplement the detail plans of the Company, showing the proposed methods of doing the work and details of construction work proposed. The tracings of these drawings or other reproducing prints shall be the property of and be delivered to the Company after the completion of the contract. All such drawings shall be made up in accordance with the AREA recommendations for drawings and drafting room practice. No changes shall be made on any approved drawing without the consent, in writing, of the Engineer. The Contractor shall be responsible for the correctness of his drawings.

Abutments, Piers, Footing Slabs, Shafts and Columns

5. Abutments, piers, etc., shall conform to the requirements of AREA Specifications for Portland Cement Concrete, Plain and Reinforced.

Concrete

6. Concrete materials, steel reinforcement and workmanship shall conform to the requirements of AREA Specifications for Portland Cement Concrete, Plain and Reinforced.

(III) CONSTRUCTION OF MASONRY

General

7. The Contractor shall submit to the Engineer and receive approval of his method of doing the work, in writing, before work is started.

Concrete Placed in a Dry Foundation Pit

8. Where concrete is placed in a foundation pit free from water, concrete may be placed against tight sheeting or forms which may be left in place below the ground line at the option of the Contractor.

Concrete Placed in a Damp Foundation Pit

9. Where concrete is placed in a foundation pit which can be kept free from water, the concrete shall be placed in the "Dry". Pumping shall be used to remove the water from the foundation, pumped directly from a sump separated from green concrete to avoid wash of concrete materials.

Concrete Placed in a Foundation Pit Containing Water

10. If the foundation has been prepared by dredging and the contact of the substructure and foundation is to be made in water, a concrete seal shall be placed by depositing concrete through water in accordance with AREA Specifications for Portland Cement Concrete, Plain and Reinforced. The thickness of the seal shall be sufficient to resist hydrostatic pressure on the structure of which it becomes a part.

11. Pumping to unwater sealed cofferdam, crib or open cofferdam shall not be commenced until the concrete has attained a strength sufficient to resist hydrostatic pressure.

Concrete Placed in a Foundation Pit Containing Foundation Piles

12. Before placing concrete around foundation piles, all loose or displaced material shall be removed so that the concrete may be placed in direct contact with the piles. If the concrete is placed through water and the piles project above the seal, the tremie method of placing concrete shall be used and the tremie shall be moved or additional tremies provided, so that concrete may be deposited without unusual disturbance and in contact with the surface of all piles. If a gravel bed is placed to separate the base of the green concrete from a soft underlying material, the gravel bed shall be grouted before the placing of concrete. In all cases the butt of the pile shall extend at least 6″ into solid concrete.

Measurement and Basis of Payment

13. The unit of measurement shall be according to legal standards of weights and measurement.

The work to be paid for shall be determined by the Engineer from the original plan dimensions, or as altered by him, applying the unit rates to the quantities so determined. The Contractor shall be paid on the basis of the original summation of his proposal, adjusted for the additions and reductions in quantities based on his unit prices for such changes in quantities.

Measurement for payment shall be as follows:

(a) Concrete seal (unit = cubic yard). The price per cubic yard shall include the furnishing and placing of all material, equipment and labor as follows:

The volume of concrete shall be the volume of a prism bounded by planes at the outside dimensions of the sub-structure of the average height of the concrete seal actually placed.

(b) Concrete footing, shaft, wall, column or bridge seat (unit = cubic yard). The price per cubic yard shall include furnishing and placing all permanent material, equipment, falsework, forms and labor as follows:

The volume of concrete shall be the volume as determined from the plan dimensions.

(c) Steel reinforcement (unit = pound). The price per pound shall include the furnishing, bending and placing of all material, equipment and labor.

(d) Waterproofing. (Unit = sq. ft. of surface waterproofed)

(e) Expansion Joints. (Unit = linear ft.)

(f) Stone facing. (Unit = square ft. of stone-faced surface)

(g) Metal nose protection. (Unit = pound)

(h) Built in anchorage. (Unit = pound)

Appendix E

(6) METHODS AND PRACTICES OF LINING AND RELINING TUNNELS

G. F. Eberly, Chairman, Sub-Committee; G. E. Boyd, Kennerly Bryan, Jr., M. F. Clements, Maurice Coburn, O. V. Parsons, R. V. Proctor, I. L. Pyle, L. W. Skov, G. R. Smiley, H. H. Temple, J. H. Titus.

SPECIFICATIONS FOR LINING RAILWAY TUNNELS WITH PLAIN CONCRETE—1935

(1) GENERAL

Scope

1. These specifications cover the lining of new tunnels and the relining of old tunnels through ordinary formations which involve no special features.

(II) DESIGN

Interior Dimensions

2. The interior dimensions shall not be less than those shown as standard for tunnels, AREA clearances.

Floor and Ballast Walls

3. The floor shall be at least 6 in. thick and shall slope ½-in. in 12 in. from the center line of the tunnel at the elevation of subgrade, towards the sidewalls. The ballast walls shall be 12 in. wide at the top and 2 ft. 0 in. wide at the floor line. The top of the walls for tangent track shall be at the elevation of the bottom of the ties. The toe of the face of the walls adjacent to the sidewalls shall be at least 12 in. therefrom (Fig. 1 and 2).

Sidewalls and Arch

4. The depth of the sidewalls, in hard, durable material, shall be at least 6 in. below the bottom of the gutter. In other material the sidewalls shall be carried down to stable foundation and at least to below the frost line.

The thickness of the sidewalls and arch shall be:

(a) When it is not necessary to temporarily support the face of the excavation:

Single Track	*Double Track*
At least 1 ft. 6 in.	At least 2 ft. 0 in.

The space between the face of the form and the face of the excavation shall be entirely filled with concrete, except that adequate drainage openings shall be provided back of and through the lining and that durable rock may be substituted to fill large holes back of the normal line of the excavation. If rock is used it shall be rammed into place (Fig. 1 and 2).

(b) When it is necessary to temporarily support the face of the excavation:

(1) Temporary Supports—Timber

Single Track	*Double Track*
At least 1 ft. 2 in. in front of the temporary supports and 2 ft. 2 in. in front of the lagging.	At least 1 ft. 6 in. in front of the temporary supports and 2 ft. 6 in. in front of the lagging.

The space between the lagging and the face of the excavation shall be firmly packed with durable stone rammed into place, or sand placed pneumatically. Lagging shall be placed only where necessary so that there shall be as many openings as possible to allow the concrete to extend to the face of the excavation. Where the entire area is lagged, lagging and packing may be removed when the concrete is placed, so that the concrete may extend to the face of the excavation. When concrete extends to the face of the excavation, adequate drainage openings shall be provided back of and through the lining (Fig. 1).

(2) TEMPORARY SUPPORTS—STEEL

Single Track	*Double Track*
At least 1 ft. 2 in. in front of the temporary supports and 1 ft. 6 in. in front of the liner plates.	At least 1 ft. 6 in. in front of the temporary supports and 2 ft. 2 in. in front of the liner plates.

The space between the liner plates and the face of the excavation shall be firmly packed with durable stone rammed into place, or sand placed pneumatically. Liner plates shall be placed only where necessary so that there shall be as many openings as possible to allow the concrete to extend to the face of the excavation. Where the entire area is plated, liner plates and packing may be removed when the concrete is placed, so that the concrete may extend to the face of the excavation. When concrete extends to the face of the excavation, adequate drainage openings shall be provided back of and through the lining (Fig. 2).

Keys

5. Each section of the lining shall be substantially keyed to each adjacent section (Fig. 1 and 2).

Refuge Niches

6. The refuge niches shall be 18 in. deep, 4 ft. 0 in. wide and 7 ft. 0 in. high. They should be spaced approximately 100 ft. apart on each sidewall and staggered so that the niches on the opposite walls shall be approximately 50 ft. apart. The bottom of the niches shall be at the elevation of the bottom of the track ties (Fig. 1 and 2).

In long tunnels, the refuge niches at half mile locations should be of sufficient size to accommodate track cars, telephones and signal systems.

The minimum thickness of the concrete lining of the niches shall be 6 inches. Provision for niches shall be made in the temporary supports (Fig. 1 and 2).

Conduits and Inserts

7. Where necessary, provisions shall be made in the lining for conduits and/or hangers for cables and wires.

Drainage Openings

8. Vertical and diagonal openings, French drains, or 3″ × 5″ rectangular tile drains shall be installed as necessary in the rear of the concrete lining, with outlets through the sidewalls to provide adequate drainage. The outer end of the outlets shall be not less than 12 inches above the bottom of the gutter. Sub-drains shall be provided under the concrete floor as necessary. Four-inch round tile drains or openings of similar area shall be installed in each 10 feet of the ballast walls to provide drainage for section of the floor between the ballast walls (Fig. 1 and 2).

(III) CONCRETE

Specifications

9. The concrete for the lining shall be made and placed in accordance with the AREA Specifications for Portland Cement Concrete, Plain and Reinforced, together with the additional provisions given herewith.

Proportioning

10. The concrete shall contain not to exceed 5.5 gallons of water (including water in the aggregate) per sack of cement, and shall have a minimum compressive strength of 3,000 pounds per square inch in 28 days.

(IV) FORMS

Length

11. The length of forms for the continuous placement of concrete between construction joints shall be limited by the ability of the placement method to provide a complete and homogeneous filling of the space behind the forms, but in no instance shall the length be more than 40 feet.

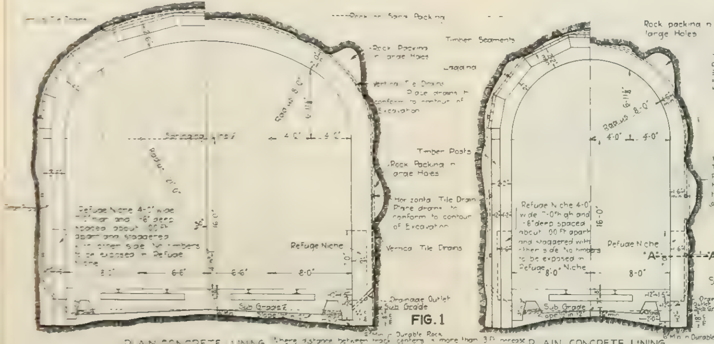
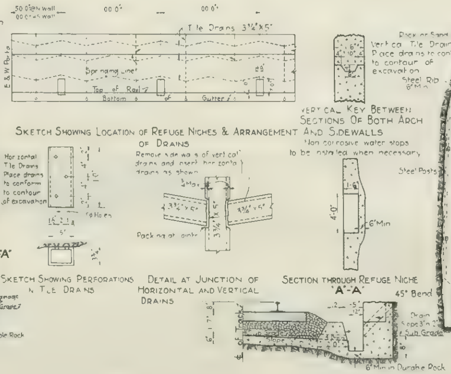

Rock or Sand Packing
Timber Segments
Rock Packing in Large Holes
Lagging
Vertical Tile Drains Place drains to conform to contour of Excavation
Radius 8'0"
6'11⅛"
Springing Line
4'0"
4'0"
Radius 21'0"
Timber Posts
Rock Packing in Large Holes
Horizontal Tile Drain Place drains to conform to contour of Excavation
Refuge Niche 4'0" wide 7'0" high and 1'6" deep spaced about 100 ft apart and staggered with other side. No timbers to be exposed in Refuge Niche
16'0"
Refuge Niche
Vertical Tile Drains
8'0"
6'6"
6'6"
8'0"
Drainage Outlet
Sub Grade
Sub Grade
6" Min in Durable Rock
Rock packing in large Holes
Radius 8'0"
6'11⅛"
4'0"
4'0"
Refuge Niche 4'0" wide 7'0" high and 1'6" deep spaced about 100 ft apart and staggered with other side. No timbers to be exposed in Refuge Niche
16'0"
Refuge Niche
"A"
"A"
8'0"
8'0"
Sub Grade
Slope ½" in 12"
Drainage Outlet
Sub Grade
6" Min in Durable Rock

FIG. 1

PLAIN CONCRETE LINING
DOUBLE TRACK TANGENT

Where distance between track centers is more than 13 ft increase distance between sidewalks accordingly. On curved track the clearances shall be increased to allow for the overhang and the tilting of a car 80 ft long, 60 ft between centers of trucks and 14 ft high. The superelevation of the outer rail shall be in accordance with the recommended practice of the A.R.E.A.

PLAIN CONCRETE LINING
SINGLE TRACK TANGENT



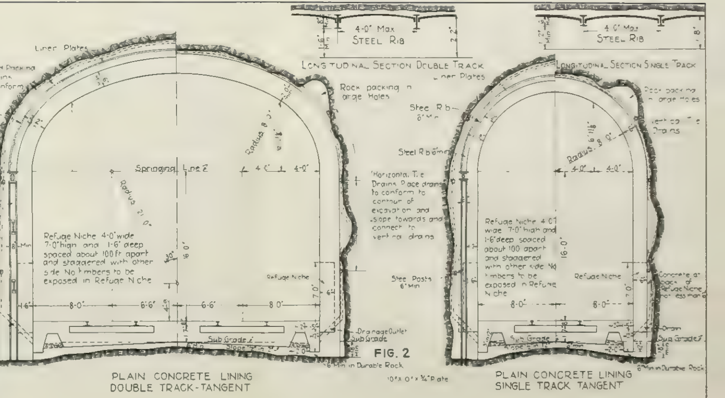
SKETCH SHOWING LOCATION OF REFUGE NICHES & ARRANGEMENT OF DRAINS

VERTICAL KEY BETWEEN SECTIONS OF BOTH ARCH AND SIDEWALLS

SKETCH SHOWING PERFORATIONS IN TILE DRAINS

DETAIL AT JUNCTION OF HORIZONTAL AND VERTICAL DRAINS

SECTION THROUGH REFUGE NICHE "A"-"A"


Liner Plates
4'0" Max
STEEL RIB
LONGITUDINAL SECTION DOUBLE TRACK
Liner Plates
Rock packing in Large Holes
Steel Rib 6" Min
Radius 8'0"
Springing Line
4'0"
4'0"
Radius 21'0"
Steel Rib 6" Min
Horizontal Tile Drains Place drains to conform to contour of excavation and slope towards and connect to vertical drains
Refuge Niche 4'0" wide 7'0" high and 1'6" deep spaced about 100 ft apart and staggered with other side. No timbers to be exposed in Refuge Niche
16'0"
Refuge Niche
Steel Posts 6" Min
8'0"
6'6"
6'6"
8'0"
Drainage Outlet
Sub Grade
Sub Grade
Slope ½" in 12"
6" Min in Durable Rock
10" x 10" x ¾" Plate
4'0" Max
STEEL RIB
LONGITUDINAL SECTION SINGLE TRACK
Rock packing in Large Holes
Vertical Tile Drains
Radius 8'0"
6'11⅛"
4'0"
4'0"
Refuge Niche 4'0" wide 7'0" high and 1'6" deep spaced about 100 apart and staggered with other side. No timbers to be exposed in Refuge Niche
16'0"
Refuge Niche
Concrete at back of Refuge Niche not less than 6"
8'0"
8'0"
Drain
Sub Grade
6" Min in Durable Rock

PLAIN CONCRETE LINING
DOUBLE TRACK-TANGENT

FIG. 2

PLAIN CONCRETE LINING
SINGLE TRACK TANGENT

Removal of Forms

12. The forms shall not be removed in less than 48 hours where the surrounding temperature is 60° or over. When the temperature is below 60° Fahr. the time shall be increased as directed by the Engineer.

(V) PLACING CONCRETE

Hand Placing

13. Concrete placed by hand shall be of such consistency that it can be thoroughly compacted to entirely fill the forms. This consistency shall be obtained without varying the water-cement ratio.

Pneumatic Placing

14. Pneumatic placing of concrete shall be done with a concrete placing machine which blows the concrete through a pipe line with compressed air. The air pressure and the consistency of the concrete shall be so regulated without varying the water-cement ratio, that the coarse aggregate shall not be blown away from the mortar matrix when the concrete issues from the end of the delivery pipe. Flexible pipe branches shall be provided, when necessary, to deliver the concrete at approximately its final position in the lining. The concrete shall be shot into a metal baffle box surrounding the end of the delivery pipe, or else the end of the delivery pipe shall be kept as close to the mass of concrete as conditions will permit, and at no time more than 5 feet away, so as to prevent separation of the mixture. Placement by this method shall be done in such a manner as to allow continuous inspection.

Pumping

15. Placement by pumping shall be done with a plunger pump which forces the concrete through a pipe line by direct pumping action without using compressed air in the line. The concrete shall be pumped as nearly as possible to its final position, using flexible pipe branches where necessary.

Shotcrete

16. Placement of Shotcrete shall be done by building up a lining by shooting on the Shotcrete in thin layers with a pneumatic hopper machine in which the properly proportioned dry cement and sand are forced through a hose to a nozzle attached to the end of the hose, where water under pressure shall be introduced into the dry mix just prior to being sprayed into place. Shotcrete shall be made and placed in accordance with the AREA Specifications for Shotcrete.

Order of Placing

17. A section of sidewalls and arch shall preferably be placed in one continuous operation. The floor and ballast walls should preferably be placed monolithically.

Compacting

18. Concrete, during and immediately after depositing, shall be thoroughly compacted, preferably by means of vibrators, which can be applied to or in the mass of concrete.

Laitance Seams and Bonding Surfaces

19. The consistency of the concrete and method of placement should be such that no laitance seams are formed at fill planes. If such seams are formed, they shall be completely removed and the forms and the progression of the work shall be such that this may be done. Concrete surfaces on which new concrete is to be deposited shall be thoroughly roughened and cleaned of all laitance, dirt and water before concrete is placed.

Drainage During Placing

20. Separate and distinct provision for drainage shall be made where necessary to prevent the placement of the concrete in water or in contact with moving water. Effective weeps and drains shall be provided where necessary to prevent hydrostatic pressure against the lining.

Curing

21. After the forms are removed the concrete lining shall be kept wet for a period of at least seven days.

Cold Weather Protection

22. In freezing weather the ends of the tunnel shall be closed and suitable means provided for maintaining the concrete at a temperature not lower than 50° Fahr. for not less than 72 hours after placing, or until the concrete has thoroughly hardened.

(VI) CONSTRUCTION AND EXPANSION JOINTS

Construction Joints

23. No construction joints or fill planes shall be formed in such locations as to reduce the effectiveness of the lining in resisting pressure from the surrounding earth or rock. When necessary, non-corrosive water stops shall be installed at construction joints.

Expansion Joints

24. No expansion joints shall be provided other than construction joints.

This report is presented for adoption to be printed in the Manual as recommended practice.

The Sub-Committee reports progress on the subject of Lining Tunnels with brick; subject to be continued.

Appendix F

(8) DESIGN OF EXPANSION JOINTS INVOLVING MASONRY STRUCTURES

C. A. Whipple, Chairman, Sub-Committee; M. Coburn, J. A. Lahmer, W. M. Ray, Geo. E. Robinson, H. F. Schryver.

Sub-Committee No. 8, Design of Expansion Joints involving Masonry Structures, collected from a number of carriers plans covering various types of expansion joints involving masonry structures to meet various conditions, and has submitted as information sketches, Fig. 1 to 21, appearing as Appendix E, Vol. 34, page 599.

The Sub-Committee made further study of the joints submitted, giving consideration to criticisms and suggestions of the various details, the results of which are embodied in the report appearing as Appendix F, Vol. 35, page 986, presenting basic principles to be observed in determining the details of expansion joints.

After having collected for three years plans covering various types of Expansion Joints involving Masonry Structures, the Sub-Committee prepared a questionnaire covering the various types, sketches of which had been submitted as information with the hope of obtaining data from the answers returned which would enable it to design approved joints for various purposes, the details of which would represent the opinion of the majority answering the questionnaire. Sufficient replies to the questionnaire were not received in 1935 to draw positive conclusions for a report to the Association, so that the Committee was able to submit only plans covering various types of vertical expansion joints involving masonry structures (Fig. 1 to 11), appearing as Appendix G in Vol. 36, page 872.

The Committee has now received fifteen replies to the questionnaire, from which to draw conclusions, and submits tabulation with specimen joints, Fig. 1 to 17, the details of which represent the consensus of opinion of those answering the questionnaire, and are the Committee recommendations.

Since each expansion joint is a problem of design to meet some particular condition and the details are an intimate part of the specifications, the Committee feels a general specification to cover the design of expansion joints cannot be prepared and recommends the report be received as information and the subject discontinued.

Appendix G

(9) STUDY SPECIFICATIONS FOR OVERHEAD HIGHWAY BRIDGES

I. L. Pyle, Chairman, Sub-Committee; F. E. Bates, G. E. Boyd, Hardy Cross, Theo. Doll, A. R. Ketterson, A. N. Laird, J. F. Leonard, G. E. Robinson, D. B. Rush, C. P. Schantz, J. J. Yates.

A revised edition of the A.A.S.H.O. Specifications has been published since the subject was assigned to this Committee. Most of the objectionable features of the old specifications have been eliminated; and, since the revised edition appeared too late to allow sufficient time for the work required to review them and prepare a report, it is recommended that this subject be re-assigned for further study.

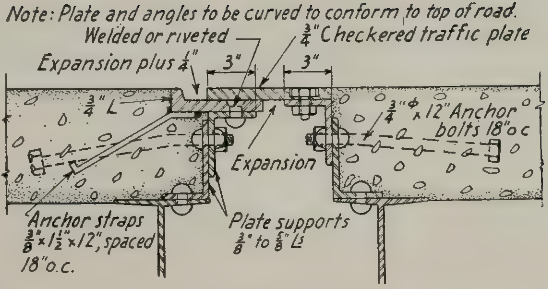

Note: Plate and angles to be curved to conform to top of road.
Welded or riveted
3/4" Checkered traffic plate
Expansion plus 1/4"
3"
3"
3/4" L
3/4"φ x 12" Anchor bolts 18" o c
Expansion
Anchor straps 3/8" x 1 1/2" x 12", spaced 18" o.c.
Plate supports 3/8" to 5/8" Ls

FIG. 1 SLIDING PLATE TYPE DECK NOT WATERPROOFED

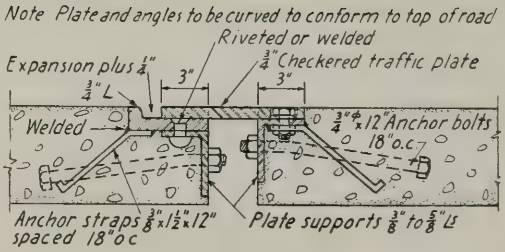

Note Plate and angles to be curved to conform to top of road
Riveted or welded
3/4" Checkered traffic plate
Expansion plus 1/4"
3"
3"
3/4" L
Welded
3/4"φ x 12" Anchor bolts 18" o.c.
Anchor straps 3/8" x 1 1/2" x 12" spaced 18" o c
Plate supports 3/8" to 5/8" Ls

FIG. 2 SLIDING PLATE TYPE DECK NOT WATERPROOFED

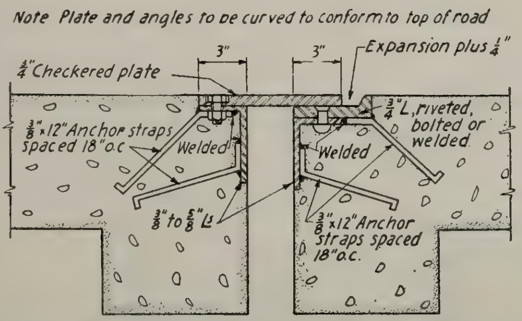

Note Plate and angles to be curved to conform to top of road
3"
3"
Expansion plus 1/4"
3/4" Checkered plate
3/4" L, riveted, bolted or welded
3/8" x 12" Anchor straps spaced 18" o.c
Welded
Welded
3/8" to 5/8" Ls
3/8" x 12" Anchor straps spaced 18" o.c.

FIG 3 EXPANSION JOINT DEVICE SLIDING PLATE TYPE

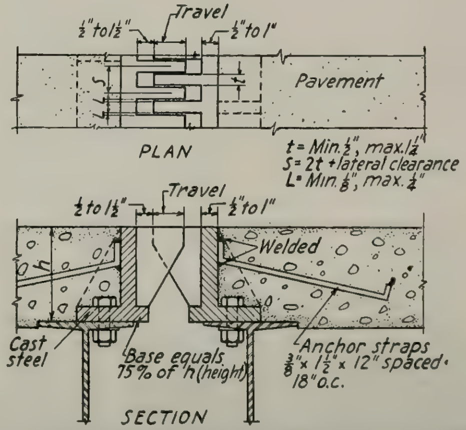

Travel
1/2" to 1 1/2"
1/2" to 1"
S
t
L
Pavement
PLAN
t = Min. 1/2", max. 1 1/4"
S = 2t + lateral clearance
L = Min. 1/8", max. 1/4"
Travel
1/2 to 1 1/2"
1/2" to 1"
h
Welded
Cast steel
Base equals 75% of h (height)
Anchor straps 3/8" x 1 1/2" x 12" spaced 18" o.c.
SECTION

FIG. 4 EXPANSION DEVICE OF INTERLACED CASTINGS

ANALYSIS OF EXPANSION JOINTS - TABULATION OF REPLIES TO QUESTIONNAIRE

QUESTION	RAILROADS								HIGHWAY DEPARTMENTS						Consensus of Opinion	Committee Recommends
	N.Y.C. & St.L.	D.L. & W.	C.C.C.&St.L.	C.& O.	B. & O.	Nor. Pac.	A.T.& S.F.	Can.Pac.	Dist.of Col.	Iowa	Michigan	New Hampshire	Missouri	Kansas		
TRAFFIC PLATES See Figs 1,5,10,19,20 (Bulletin 393, P.393)																
Material?	Cast Steel	Steel	Steel	Steel	Copper Bearing Steel	Struct. Steel	Steel		Struct. Steel	Steel	Struct. Steel	Structural Steel	Struct. Steel	Struct. Steel (Copper Bags) or Cast Steel	Steel	Steel
Thickness?	¾"-Min. thick to give noise a deeper note	½"	½"-⅝"	Heavy enough to lie of own wt. to avoid rattle	⅝" Min.	½"	⅝"		Varies with span of plate minimum ½"	Min. ⅝"	¾"	Minimum ¾"	¾"	Des. for wh. load & tire pressure Depends on type	¾"	¾"
Surface - Plain or Deformed?	Deformed	Deformed	Plain	Deformed	Prefer Deformed	Deformed	Deformed		Deformed	Plain	Tried both Pref. of			Plain is O.K.	Deformed	Deformed
What kind of deformation?	Raised Diamond	Checkered		Transverse to traffic	Grooves	Checkered	like Carn. Floor plate S-300		Any standard type		Any st rolling with app.1/8" lug	Checkered			Checkered	Checkered
Should they be easily renewable?	Reasonably so	Yes	Yes	Yes	Yes for examples shown	"	If possible		Yes	No	Not necessary	Gen. No-Depends on design and loading	No-Fasten rigidly	Not necessary if properly designed	Yes	Yes
How should they be anchored?	Bronze tap screws	Removable bolts	To steel and also to conc.	Set Screws	Diagonal straps	Rivets	Riveted		Riveted	Anchor to Steel	Weld or rivet to anchorage	Weld or countersunk rivets	Direct to Steel	Weld or a lot of countersunk rivets.	Rivet	Rivet or weld
Minimum bearing - anchor side?	2½"	3"	3½"	2"	3"	1½"	3"		Edge dist fixes	2½"	2½"	Minimum 3"	4"		3"	3"
" " - sliding side?	2"	3"	3½"	2"	3"	1½"	3"		Vary with span usually 1"	2"	2"	" 3"	2"		3"	3"
Is noise a valid objection to their use?	Not if thick plate is used	Yes	Yes	Yes, in settled vicinities	Yes	Rarely	No		Yes	Yes	No	No noise if properly erected	No noise if prop. fit and rig. fastened	Yes	Yes	Yes
If traffic plates are not used, what should be used?		Filled Open Joint	Use plates	Interlaced teeth	Steel Castings						Steel shapes as Fig. 3 or Filled joint	Interlaced bars	Toothed Castings	To 1" Bit. filled Wide-interlaced	Interlaced or Filled	Interlaced
Should the sliding clearance be filled?	No	Yes	No	No	No	No	No		No	No		Partially	No	Yes, if a lateral groove.	No	No
If sliding clearance is filled - with what?		Plastic material	Mastic						No		Asphalt mastic	Asph. cracked filler-heavy paint coat		Non-extruding bitumen joint cork or rubber	Mastic	Non-extruding filler
SUPPORTS FOR TRAFFIC PLATES																
Material?	C.P.Steel	St. or conc.	Steel	Steel	F.P.Steel	12" Channel	Steel		Pref. str. st.	Steel	Struct. steel	Str. st. shapes	Str. st.	Copper steel	Steel	Steel
Thickness?	5/8"	⅜" Min. St. 6" " Conc.	3/8"-½"	Min. 3/8"	5/8"		Deps on spacing of stringers		Des for load min. 5/8"	Min 3/8"	3/8"-½" Ls or shapes	Min. 5/8"	¾"	Minimum 3/8"	3/8"- 5/8"	5/8"
Should they be easily renewable?	No		Only in slab renewal	No	Not necessary	No	Not necessary		Desirable		Not necessary	Pref no-Renewal type hard to keep tight	No att. rigidly	Not necessary if properly designed	No	No
Should horizontal leg be anchored?	Yes	"	Yes	Yes	Yes	Rivet base to fl. supp.	Yes		If in conc. Rivet to St.	Yes	Yes	Yes, have used without anch. O.K. to date	Rigidly attached to steel	Best unless gap is short.	Yes	Yes
" vertical " " " ?	"	"	"	"	"	Bolt web to conc. slab	"		Anchor " Con.	"	"			Yes	"	"
With what?	Bent anchor bolts	Screw anchor bolts	Anchor bolts or straps	Anchor bolts or equal	St.-rivet Concrete-Misc. bars		Steel-rivet Concrete-Anch. Bolts or Bars		Bent bolts or bolts and Bars	Rivets	Anchor bolts	1"x1/4"x12" Flats-welded connections		Welded bent dowels or bolts-head exposed	Anchor bolts	Anchor bolts
ANCHOR BOLTS FOR SUPPORTS																
Material?	Iron	Steel or bronze	Steel	Steel	Steel	St. Steel	Steel		Str. Steel			Steel	St. Steel	Copper Steel	Steel	Steel
Size and length?	¾" L = slab depth	¾" Min.	⅝" to ¾"x12"	¾"x6" Min.	7/8"x12"	¾"x2'1" 2'4"ctrs.	¾" Min. embed app.12"		¾"x10" to12"			¾"x12"	¾"x6"	¾" - Develop Strength of Con.	¾"x12"	¾"x12"
Detail of buried end?	Head & washer	Normal	Nut or head	Nut	Head	2"sq nuts	Usually plain		Nut			sq.hd.nut wash.	Hex head	Bent or head Vary for good emb.	Head	Head and washer
Normal to leg or inclined?	Inclined	Normal	Either, to get best hold in slab	Normal	Prefer Inclined	Normal			Inclined			Inclined	Incl. incd	To avoid encircling small chunk of con.	Inclined	Inclined
Head or nut exposed?	Nut	No	Nut	Not necs.	Nut	Head			Head			Ten nuts one exposed	Nut	If clear allows	Nut	Nut
ANCHOR STRAPS																
Material?			Steel	Steel	Steel		Steel		Struct. steel	Steel	Struct. steel	Steel	St. steel	Copper steel	Steel	Steel
Size and length?			1/2"x5/16" Length varies	1"x⅜ 6"x6" Min.	2"x3/8"x12" Min.		1"x¾"welded or min.1" riveted		3/8"x2½"x 10" or 12"	2"x5/16"	1/2"x3/8"x 12"	1"x1½"x12" at 12" centers	2½"x3/8"x16"	About 2"x5/16"		3/8"x1½"weld 3/8"x3"rivet
Detail of buried end?			Hook	Plain	90° bend		Plain		Bent	Hook	90° bend	Straight	Hooked	Bent	Bent	90° angle
Normal to leg or inclined?			Either	Inclined	Inclined		Inclined		Inclined	Inclined	Inclined	Inclined	Inclined	See above	Inclined	Inclined
Riveted, bolted or welded to angle?			Either	Welded	Welded		Either		Either	Either	Welded	Welded	Riveted	Good butt weld	Welded	Either
When supports rest on structural steel, should they be riveted or bolted?	Riveted		Riveted	Riveted	Riveted		Riveted		Riveted	Riveted	Riveted	Prefer Riveted Because both	Riveted	Better riv.-Bolt OK with lock nut weld if practic.	Riveted	Riveted
CONCRETE ADJACENT TO SLIDING CLEARANCE																
Concrete Square - Beveled - Rounded?		Rounded	Beveled	Fig.21 OK Beveled	Square				Rounded	Beveled	Square	Square			Square	
Metal Edge. Bar - Angle or Channel?	Bar	Channel	None	Fig.21 OK	Bar	Channel	Angle		Angle		Angle	Angle	Angle	Bar-others OK but more expen.	Angle	Angle
Supported on what?	Same as traffic plate				Steel	St.Str'g.	Steel or conc. most convenient				Str.conc.with thick slab	Concrete		Edge of lower sliding plate	Steel	Steel
How anchored?	Riveted	C S Rivets			Welded	Rivets	See above		Bolts or bolts & bars		Anch. bars	1"x1/4"flats		Welded		Countersunk rivets
INTERLACING TEETH																
Material?	Cast steel	Steel	Cast steel	Steel	Cast st.	Not used	C S or rolled		Not used	Not used	C S or str steel welded	St. cast-used no castings yet	Cast Steel	Copper steel	Cast steel	Cast steel
Thickness? for 2" travel " 10" "	Half length 2" Max.	1"	¾" to ⅞" ¾" to 1"	Depends on wt. truck	1" 1"		Dep.on travel Det.by designer				1¾"-cast ¾"-struct	1"x3" 1½"x3"	1¼"	1¼"		3/4" 1¼"
C to C of opposing teeth? " 2" " " 10" "	1-1/4" 2-1/2"		Thick + 1/16" "	do "	1¾"		do				1-1/2"		2" to 2½"	max. 6"		To give 1" clearance
Lateral clearance? " 2" " " 10" "			1/32" "	1/8" "	3/8" min.		1/4"				1/8"	1/4"		1/8" each side	1/8" to ¼"	1/4" 1/2"
End clearance-full expansion? " 2" " " 10" "	1" 1"		1" 1"	1/4" 1/4"	1" min.		3" 12"				1/2"	1"	1½" min.	1/2"	1/4" to 1½"	1" 1"
Thickness of web?	1"		1/2" to 3/4"	Depends on weight on the truck wheels	3/4"		Should be handled by designer				1" casting		Dep.on type & fastening		1/2" to 1"	1"
Width of base (% of height)?	75%										75% "				75%	75%
Spacing of ribs?	Design Maximum 18"		Dep.on meth. of anchoring		6"						15" "	Bars welded to struct. shapes	3"-3½"			Design
Thickness of ribs?	1"		1/2"		3/4"						1" "		3/4"	3/4" to 1"	3/4" to 1"	¾" Min.
When supported on structural steel - Should they be riveted or bolted? Why?	Riveted Avoid opening jt. with conc.	Bolted So can be removed	Riveted Bolts will work loose	Bolted Rivets do not hold	Riveted Tighter fit						Bolted for adj. during & after const.		Bolted- More positive & removable	Welded No room for bolts or rivets	Bolted	Riveted. Tighter to avoid play.
Which of the three following practices do you prefer: A-Special patterns for each job. B-Set of patterns with height varied, adapted to a job by adding to top of pattern to conform to crown. C-Set of patterns, various heights,-casting ground to conform to crown	B	B	A or C depending on frequency of use	A	B		Don't know whether B or C would be cheaper				A Because of infrequent use		A	A	A	A
What length of castings?	3'		To 4'-300#	About 5'							About 4'			10' most conven.	3' to 5'	[illegible]
Should they be connected on steel when supported?	Yes		Yes	Yes	No		No				Yes			Yes. In any case.	Yes	Yes
" " concrete	"	No	"	"	Yes		"				"				"	"
Should traffic plates be used with interlacing teeth - Why?	No Unnecessary	No rattle	No. No need prob. noisy		No Unnecess.		No objection if drainage is OK				No. Not necessary		No. No need		No Unnecess.	No
IN A HORIZ.JT. CARRYING FULL LOAD I.E. NOT A FLOORBEAM FRAMED INTO A GIRDER OR TRUSS																
What mat. for bear.pls.-steel, zinc, bronze, exp.jt.mat., tar paper, copper, lead or what?	Steel	Plastic Fill or Premolded	Steel	Bronze	Premold. exp.jt. mat.	Manilla paper	Steel, zinc bronze, copper		Steel for light load; bronze for heavy load	Steel	Steel, premo.exp.jt. mat., rail emb.in con.	Steel with two layers asbestos paper between		1/8" sheet asbestos	Steel	2 sheets of steel with 1/8" asbestos between
How many - 1 or 2?	2		2	2	1	2	2		2	1	1	2			2	2
How attached to concrete above?	Imbedded in		Anchor bolts or straps	Anchor bolts	Not attached		Unimportant		Anchor bolts		Pls. anchored	1"x¼" straps or ¾" bolts		Not necessary	Anchor bolts	Anchor bolts
How attached to concrete below?	Anchor bolts										Pls. & jt mat. not anchored			Wire		
Should bearing be above general level of pier top or bridge seat?	Yes			Yes		No			Yes	Yes	Yes, for steel	Yes		Preferably	Yes	Yes
If so, how much?	2" min.		1/2"						1"	2" min.	2" min.	1/2" min.		1" min.	2"	2" Min.
IN A HORIZ.JT.NOT CARRYING FULL LOAD-FLOORBEAM																
Bearing plate - material?	Steel	As	Prem.jt.mat. or terra felt				Have never had occasion to provide a joint at the end of a floor beam				Riveted connection usually no plate used	Steel Angles			Steel	Steel
How many?	2											2			2	2
How attached to concrete above?	Angles	above	Not attached	under-								1"x¼" straps			Anchor	Anchor
" " " " below?	Anchor bolts											or ¾" bolts			Bolts	Bolts
Should bearing be above gen.level of br.seat?	Yes		Yes	stood								Yes			Yes	Yes
How much?	2" min.		1/2"									1/2" min.			1/2"	2"
IN A VERT. SLIDING JT. BET. CONCRETE SURFACES SUCH AS A DECK SLAB PASSING THE TOP OF A WING																
Should any material be used in the joint?	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Only when forming is difficult	Yes	Yes
What?	Tar Paper	Plastic Cem.-Asph.	Tar Paper	Ex.Jt.Mat	Ex.Jt.Mat.	Elastite or Zinc	Metal	Elastic Cement	Elastite		Ex.Jt.Mat. use cork	Cork with one ply asb.paper	Rubber Compound	Prem.non-extru. type bit.joint	Ex.Jt.Mat.	Cork
How thick?	2 ply			1/2"	1/2" Min.	¼" or Zinc #12 gauge	Sheets	About ¼" Fill.cir.	1/4"		1/2"	1/2"	3/4"	1/4"	1/4"-1/2"	1/4"
How many layers?	2		2 or 3	1	1	1 or 2	2		1		1	1	1	1	1	2
How attached?	Temp.only-for construction		Adhesion	Galv.nails	Not att.	Staple to one surf.	Loose		Nail to one side if des.		Only temp. for const.	Bit.cement towing	Cop.wire stitched	Can be fastened with wire		Wire stitching
IN A JOINT BETWEEN TWO CONCRETE FLOORBEAMS OR HEAVY CONCRETE SLABS IN A HIGHWAY BRIDGE (excluding jts using interlacing teeth)																
Should joint be covered with a traffic plate?	Yes	No	Yes	No-Assume like Fig.15	Yes		Yes		Yes, in openings over 1"	No	Yes, except short span	Yes	Only over 1"	Not if less than 1"	Yes	Yes
(a) Should joint be filled? With what?	No	Yes, Plastic Filler	Yes, Cork & Mastic	Yes Elastite	No		Who knows? Everybody uses asph.	Elastic Cement	Poured fill. If under 1"	Prem.ex. jt.mat.	Short span cork	No	Yes, Rubber Comp.	Yes, Rubber or Cork	Yes	Yes Cork
(b) Should joint be drained near top with gutter or similar device?		Yes		No	Depends on Conditions		All this dep. on conditions. If deck can be drained lengthwise no down spouts required		Copper flashing in concrete or gutter under open joints	Yes		Yes	Yes		Yes	Yes, with gutter
(d) At the bottom into down spouts?	Open, removable non-cor. gutter			No											No	No
(e) How conducted from along jt. into d'spouts?																
(f) At the bottom running over pier top (In this case bearing is above pier top)?															No	No
(g) No provision for drainage at all (floorbeam or slab setting directly on pier top)												Generally not used			No	Provide drainage
(h) Should smoke be kept out of this joint?	Yes	No	Yes	No	No, can't be done				Desirable	Yes			No	Yes, Coating of asphalt	Yes	Yes
(j) How?	With gutter															
(k) Why?	Avoid damage to conc. & steel		Causes deterioration						Corrosion [illegible]						Avoid deterioration	
SAME AS ABOVE EXCEPT USING INTERLACING TEETH?																
(a) Should joint be filled? - With what?	No		No	No	No	No exper.	No		Not used	Not used	No	No	No	No	No	No
(b) Should joint be drained near top in gutter?	Yes	Yes		No	No							Yes	Yes	No	Yes	Yes
(c) What material for gutter?	Non-corrosive	Copper											Copper	Provide Intercepting deck drains	Copper	Copper
(d) At the bottom into down spouts?															No	No
(e) How conducted to down spouts?			Cop.gutters												Cop.gutters	
(f) Running over pier top?															No	No
(g) No provision for drainage at all?															No	Prov.drain
(h) Should smoke be kept out of this joint?	Yes	No		No	No								No	Paint, hvy. asph. probably best	No	Not neces.
(j) How?	With gutter															
(k) Why?	Avoid damage															
SAME WHERE CONCRETE SLAB RIDES ON STEEL STRINGERS OR FLOORBEAMS-USING INTERLACED TEETH																
(a) Should joint be filled? - With what?	No	No	No	No	No	No exper.	Depends on conditions		Not used	Not used	Not used	No	No	No	No	No
(b) Should jt. be drained near top into gutter?	Yes											Yes	Yes	No		Yes
(c) What material for gutter?	Lead												Copper			Copper
(d) At bottom into down spouts?																No
(e) How conducted to down spouts?			Cop.gutters													Gutters
(h) Should smoke be kept out of this joint?				No									No		No	Not neces.

ANALYSIS OF EXPANSION JOINTS - TABULATION OF [illegible] QUESTIONNAIRE

QUESTION	RAILROADS								HIGHWAY DEPARTMENTS						Consensus of Opinion	Committee Recommends
	[illegible] & St.L.	D. L. & W.	C.C.C.&St.L.	C. & O.	Wabash	Nor.Pac.	A.T.& S.F.	Can.Pac.	Dist.of Col.	Iowa	Michigan	New Hampshire	Missouri	Kansas		
[illegible] OF STEEL STRUCTURES [illegible]																
Should bearing plate or bolsters be used? What metal?	Yes Steel		Yes Steel	Bolsters Steel	Steel		Should use sole pl & mas.plate Steel	Yes Steel	Steel-light load Bronze-heavy load	Yes Steel	Yes B.orz.St.	Yes Slid.or Cast St.	Yes Steel	Sh.mat betw'n cold roll.plates. Bronze st.pls.	Yes Steel	Yes Steel
Should bearing be above gen. surface of br.seat? How much?	Yes Min. 2"		6" to 10"	Yes 1/4"		1/2" to 1"	Mount.on br st.	Yes 7/8" Min.	Yes 1"	Yes Min.1/2"	Not nec.	Yes Min. 1"		Min.1/2"	Yes 1"	Yes 2" Min.
WHEN SLIDING SPAN IS STRINGERS INDIVIDUALLY ENCASED									Entirely enc. stringer including 2" over end (se sole pl. as thick as encase placed against it—not lower than plane of sliding							
a Should encasement—Stop at expansion distance in the clear of bridge seat?	No		No	Yes, unless high shoe be used			No	Not unless extending is impractical.					Yes	No	No	No
b Extend over bridge seat stopping exp distance from bearing plate?	Yes		Yes	Yes		Yes	Extend over B.S. to end of beam	Yes, if practic.						Yes	Yes	Yes
c In the latter case should bottom of encasement be flush with bridge seat?	No		No	No Use bolst for clear.		No	No	No		No			Yes		No	No
Be kept clear of br.seat by form board to be removed or by expansion joint material?	Exp.jt.mat.		Exp.jt.mat.			Form board	Either	Form board		Exp.jt. mat.	Exp.jt. mat.	About 2"	Either	Exp.jt. mat.	Exp.jt. mat.	Exp jt. mat.
d What material?	Cheapest						Exp jt.board or as sat.lay.			Prem bit	Cork	Bit.felt	Rub.Comp.	Bit.jt.mat.	Bit jt.mat.	Bit jt.mat
How thick?	1/2"		1/2"							3/8" min.	¼" to ½"			1/2" min.	1/2"	1/2" Min.
WHEN SLIDING SPAN IS SOLIDLY ENCASED i.e., under side is flat									Grout bed plates to grade with not over 1" of grout. Clearance betw encase & bridge seat is the thickness of grout plus bed plate.							
Should encasement—Stop at expansion distance in the clear of bridge seat?	No						No						No	No	No	No
c Extend over bridge seat stopping exp.distance from bearing plate?	Yes						Extend to end of beam	Yes					Yes	Yes	Yes	Yes
In the latter case, should the bottom of the encasement be flush with bridge seat?	Keep 6" clear. For man to get in to remove gutter for cleanout when necessary						No	No					Yes		No	No
Be kept clear of br seat by form board to be removed or by expansion joint material?			Exp.jt.mat.			Form board	Either Exp. board	Form board		Exp.jt. mat.	Exp jt mat.			Exp.jt. mat.	Expansion jt.material	Expansion jt.material
d What material?										Prem.bit.	Cork		Cast or rub.comp.	Bit.joint		Cheapest
How thick?			1/2"				Depends on exp.			1/2"	1/2"	1/8"		Min.1/2"	1/2"	1/2" Min.
IS BALL. SLAB SHOWN IN FIG.20 a desirable substitute for a tread plate?	No		▨	▨					Not used		No	Believe not	B	No	No	Yes only for economy
Is upper part to be filled? With what?		Plast filler				Asphalt	Exp jt.filler	No				Asp.cork filler	rub comp			Rubber comp.
" lower " joint " " "		No					" " "									No
How should edges exposed to traffic be treated.		Protected by angles					Ang protectors anch'd.in con.					If used	Round edges & fill with asp.		Protected by angles	Protect by angles
TRANSVERSE JOINTS FOR BALLAST FLOORS Kindly answer the questions below on the right for a concrete main slab or completely encased beams flat bottom. On the left answer for the ordinary 6" or 12" slab on stringers or I'beams	Editor's note:- The respondents made no distinction between the two types of construction.						Same ans.both sides as we put 4" conc.on top of encas beams —Do not sep'r'd.									
TRANSVERSE JOINT OVER A PIER- (WATERPROOFED). Figs 8, 9, 10, 12																
Should some form of loop flashing be used?	Yes	Yes	Yes	Yes	No	Our experience with heavily loaded, small, sections does not favor this design.	Yes	Yes	Do not use			Preferably Yes	We use no ballasted floors	No experience	Yes	Yes
If so, should there be one or two?	2	1	2	1			2 preferably	1		1		1			1	1
If one, should it be over or under the membr.?		Under		Under			Under	Under		Under		Under			Under	Under
Should loop be up or down?	Up	Down	Up	Down			Either for	Down		Down					Down	Down
Why?	Can't fill with foreign matter	Less likely to be damaged	Less likely to be fouled	Close to top as possible			convenience	For prot of loop				Usually filled with asphalt				
How deep a loop?	About 6"	Dep.on dist.bet. exp.jts min.4"	3" to 4"	2"			Dep.on exp.say 2" average case	2" min.		1" min.		3" min.				4" min.
How wide a loop, i.e., diameter of bend?	1" lower 2" upper	2"	1"	Dep.on mat.exp.			Depends on room much as poss.	1½"-2" for av.[illegible] mat.				2"			2"	2"
What material? - Why?	Zinc - ductile non-corrosive	Copper Lasts longer	Lead - less crystalis.	16 oz.cop. will last			Non-corrosive metal	16 oz.cop. flexible		Copper		16 oz. cold rolled copper dur.& pliable			16 oz.copper	Lead Less crystal's
When it is necessary to make a turn, i.e., where the parapet joins the floor, should the flashing be continued in one piece, i.e., separate pieces soldered together or should the pieces be absolutely separate?	Absolutely separate	One piece	Separate	Two pieces soldered			Wouldn't use flashing in general	Difficult to make proper job without soldering		Separate pieces soldered together		Prefer single piece			Soldered together	Separate Soldered bends are stiff and liable to crack concrete
Draw a free hand sketch of flashing you prefer?																
How should top flashing be attached? To what?	Adhesion Membrane	By angle To concrete														Adhesion Memb.& Prot.Ct.
How should bottom flashing be attached? To what?	Roofing nails Creo.2x4 in con.	Not attached														Roofing nails Creo.2x4 in con.
IF LOOP IS UP How far below the top of the protection coat should the loop of the s) bottom (inside, flashing be? t) top (outside) " "	3/4" 3/8"		1/2"													Use for joints in arch parapets etc. 7/8" 1/2"
(u) Should opening between slabs below flashing be filled with anything-what?	Exp.jt.mat.to bottom of flash. for thick slab		Cork				▨									Cork
If expansion joint material is used, how thick per inch of expected expansion?	3"		1½" 1/4" min.	1½"												Use manufr. recommendation
(v) How supported?	Nail to 1 slab			Galv.nail												Nail to 1 side
IF LOOP IS DOWN Answer same questions. s t		6" 6"										No experience				6" 6"
(u)		Plastic filler		Not if forms can be removed								1½" cork,bit. treated Celotex or rubber				Plastic filler
(v)		In loop		Galv. nails				Not neces.								In loop
Should the surface of the main slab be raised adjacent to the joint? How much? Why?	No	Yes, 2" - 6" dep.on avail. depth - drain away from jt.	▨			1½" to lead drainage away from joint	Prob.desirable where possible.	Preferably 1" Drain away from joint							Yes Drain away from joint	Yes 2" Minimum for drainage
If main slab is kept level, should protection coat be thicker adjacent to the joint? How much? Why?	Not necessary	Yes See above		Level			If expan is not over 1", leave membrane full, 12" ea.side of and over joint	2"-To keep water from jt.in case of flood.				Protection coat has pronounced tendency to break down here				This will not protect from water under protection coat.
TRANSVERSE JOINTS AT THE ABUTMENT																THICK SLAB / THIN SLAB
Should this jt.be similar to that over a pier and placed between backwall and slab or should it be a horiz.jt.-the slab sliding over the backwall. If the former, we assume that the details are the same; if not, please note differences?	Horizontal	Not sliding	Horizontal	Horiz.		Our bal.dk. abut.jts. are exp.jts.sliding over B'wall	Horizontal	Horizontal				Very successful with hor. jt.—2 ply asb. paper between slab & B'wall			Horizontal	Horizontal
If the latter, i.e., horizontal, should an apron plate be used? What material? How thick?	Thin slab—3/8" steel. Thick slab—tar paper		3/8" steel	No	N.	No	Not necessary in ordinary case	Preferable				No			No	No Yes 3/8" st.
Attached to span or backwall? How?	Span - rivet		Span-rivet					Span - bolt							Span-rivet	Sp.-riv.
Should waterproofing stop on slab or go down back of abutment? How far?	12" below bridge seat	2'	To bridge seat	Down 12"	Down back 15"	9" below joint	Down back	Down back 30" min.				Down back to cover pl. +12"				1' below joint 1' below br.seat
Should protection coat stop on slab or go down back of abutment? How far?	Stop on slab				Stop on slab		Down back about 12"	Same as W'proofing				Stop on slab			Stop on slab	Follow waterproofing
Should the edge of the main slab be rounded? What radius?	Yes 1"	Preferably Immaterial	Beveled 3"	No	Yes	Yes 6"	Yes	Yes About 6"				Pitched			Yes 6"	Yes 12" To angle
Should edge of slab be protected by an angle? What size and thickness?	Yes 3½"x3/8"	If not round 4"x4"x1/2"	3-1/2"x3/8"		No	No		Not neces.				Yes 4"x4"x3/8"			Yes 3½"x3/8"min.	No Yes 3½"x3/8"
What kind of protection coat did you have in mind when answering the foregoing?	Concrete	Asp.blk -flat Asp.plastic on brick-vertical	Concrete	Conc. or asph.plk.	Concrete	3" Con.over 1" asphalt plank	Asphalt mastic on plank	Mastic				Concrete			Any	
On the joint shown on the attached print, do you approve the tail plate idea? What material? Thickness? Length?	Yes Steel 3/16"x16"	No	Yes Steel 1/8"x16"	No	Yes Steel 5/8"x12"		No	No				Yes Cop.bear.steel 5/16"x18"				Yes 3/16"x18" Steel
LONGITUDINAL JOINT BETWEEN TRACKS - Slab on girders. Should it be--open, unprotected?	No			No			No					Have no call for this design			No	No
Covered? With what?	Only over street Steel channel			Yes, W'prf. Fabric	Yes, steel	Steel	Yes membrane								Yes, bent steel plate	Yes, 1/2" bent steel plate
Filled with what? Thickness?	Exp.jt.material 2"	Plast.filler 1"		Elastite 1/2"		Elastite 1/2"	Exp.jt.filler Dep.on condit.								Exp.jt.matl. 1/2" min.	Cheap jt.mat. 1-1/2"
How far down?	4" from bottom	To loop metal				Full depth										4" from bottom
How is filler supported?	Con.lip on slab	" " "		Nailed		Nailed	Like Fig.12									Lip on 1 slab
If filled only part way or not filled at all, what clearance should there be between slabs?	7/8"	Min. 1"					Depends on movement								1"	5/8"
Should flashing be used? If so, is it the same as you use in a transverse joint, if not, what differences?	No	Yes Yes	Yes Yes	Yes Yes		No	Yes Yes								Yes Yes	No
Should protection coat (slab level) be raised adjacent to the joint? How much?	Follow slab	Yes sev. inches		No	Yes 2"	Yes 1½"	If convenient Few inches									Follow slab
Should slab be raised adjacent to the joint? How much?	Yes 2" min.	In a dam 3" to 6"	Yes	Yes 1/2"	Yes 3"	1½"	Some								Yes	Yes 2" minimum
HOW MUCH EXPANSION DO YOU ALLOW PER 100' STRUCTURE? Where structure is-All steel?	1"	1"		1"	2" to 3"	Based on coef expan.& const. temperature as well as climatic extremes	1"								1"	1"
Ballast deck on thru steel?	1"	1"		1"	1½"		1"								1"	1"
" " " deck " ?	1"	1"		1"	1½"		1"								1"	1"
Concrete?	1"	1"		1"	1½"		1"								1"	1"
VERTICAL JOINTS IN RETAINING WALLS How often in a reinforced wall?	50'	30'	50' Max.	30'	30' - 40'	50' in heavy abutment.	30' to 60'	About 100'		50' min.		30'		About every 30' or 40'	30'	30'
" " " " gravity " ?	50'	30'	50' Max.	30'	40'	25' in 9' wall	20' to 40'	30' - 40'		50' min.		40'		30' or 40'	30' to 40'	30' to 40'
Keyed for alignment? Sketch key with dimensions.	Yes	Yes	Yes	Yes	Yes	Yes	Yes or reinf.	Depends on thickness of wall. 4" and up		Yes		Yes Depends on height, etc.		Yes	Yes	Yes Des.for equal shear. Provide slight draw.
When wall has pilasters, give a sketch showing where you make the joint?							At the side of pilaster	Depends on [illegible]		Side Joint						See specimen joints
What expansion joint material do you use? How thick?	Cork 1/2"	Asph.Cement 1"	Cork 1/2"	Elastite Varies		Elastite 1/2"	Elastite	Lead or cop. 1/8"-16 oz.		Prem.bit. 1/2"		Cork		Prem.non-extrud.bit. 1/4"	Cork or Elast. 1/2"	Cork 1/2"
Do you use French drain at the joint?	Yes	Yes	Yes	No	No	No	Not usually	Sometimes		Yes		Usually		Sometimes	Yes	Yes
What material?	Broken stone	Varies	Loose rock				Rock or gravel	Vitrified						Cr.rock	Broken stone	Broken stone
Do you use pipe drain at a joint?	Yes, Perforated	Sometimes	Yes. Perf.	No	No	No	Sometimes	Sometimes		No		Near joint		Perf.CM pipe	No	Yes
What kind?	Corrugated iron	Concrete	Corrug. Iron				Tile	Iron				4" hole		Spec.5 point	Iron	Corrugated
What cure have you for extruding expansion joint material?	Use 4" strip at front & remove	None	Rake out 1" back fr. face	Put behind cop. drain	▨		Keep elast 1" back from face			Bevel edges				Use non extruding type Dep.on supp.	Keep back from face	Rake out strip next to face.
VERTICAL JOINTS IN PARAPET WALLS Keyed for alignment? Sketch key with dimensions.	Yes	No	Yes	Yes	No	Yes	Not usually retired	Yes, Usual Types				Not usually			Yes	Yes, Same as above.
When wall has pilasters, give sketch showing where you make the joint?	Same as above	As above. Behind pilasters		Same as above	Don't use pilaster		At side of pilaster	Dep.on des. of pilaster								See specimen joints
What expansion joint material do you use? How thick?	Cork 1/2"	1" Asphaltic Cement	Cork 1/2"	Elastite Varies	1/2" Exp. Board	Elastite	Elastite 1/2" to 3/4"	½" Elastic Cement				Cork 1/2"		Non-extruding premolded bit.	Cork or Elastite - 1/2"	Cork 1/2"
When the structure is waterproofed, how far up the wall do you waterproof?	To 4" from top	To coping	Base of rail	Base of rail	To 6" from top	To top of fill	Depends on conditions	To above sidewalk				To grade line at curbs		Up to where it will still be buried out of sight	To base of wall or grade	6" above grade
What kind of protection coat?	Concrete	Cem.plaster or hollow tile	Asphalt Semistone	Conc. or asph.plk.	Conc. or [illegible]plk.	2 coat hvy. asph.paint	3 ply membrane or Brodeproof	Mastic				Bit. with, or without fabric			Concrete or asph. plank	Conc., asphalt plank or mastic
Do you flash? How many?	Yes - 2		Yes - 2	No	No	No	Details depend on structure	Yes - 1				Yes - 1		No		Flash - 2
Where does flashing start - top flashing? - bottom " ?	Top of arch " " "	At footing										At bottom of wall				Two flashings with membrane—extra piece of top flash. cast in coping over top & 6" down on the outside.
" " " and - top " ? - bottom " ?	6" down outside 4" " inside	At coping										At grade				
If your flashing is placed differently, or is different than the flashing you described for floors, note the differences.																

* Key thus if pilaster projection is small and support not enough to keep in line. If no backfill between parapets or balustrade, use an open joint 1" wide made with steel plates subsequently removed.

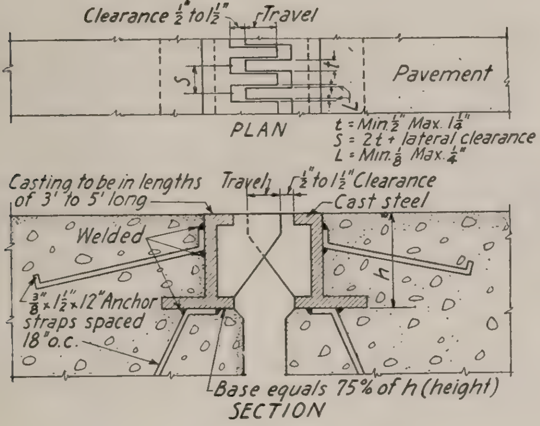

Clearance ½" to 1½"
Travel
S
Pavement
PLAN
t = Min. ½" Max. 1¼"
S = 2t + lateral clearance
L = Min. ⅛ Max. ¼"
Casting to be in lengths of 3' to 5' long
Travel
½" to 1½" Clearance
Cast steel
Welded
h
⅜" × 1½" × 12" Anchor straps spaced 18" o.c.
Base equals 75% of h (height)
SECTION

FIG. 5 INTERLACED CASTINGS

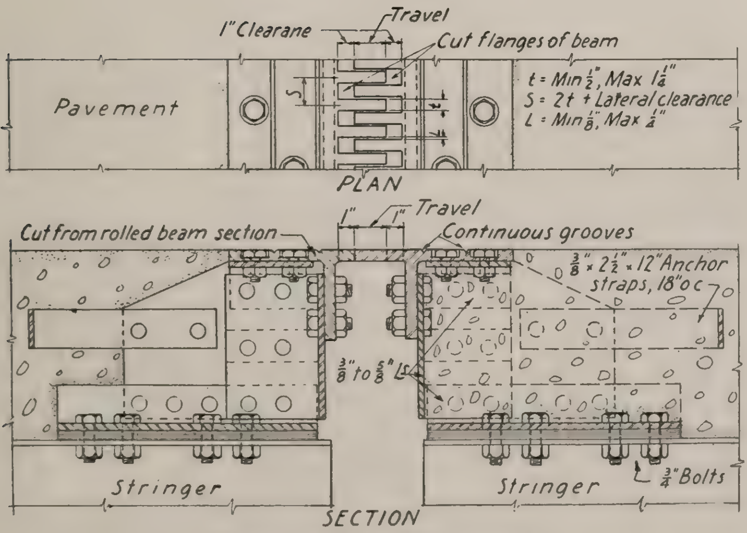


FIG. 6 INTERLACED JOINT

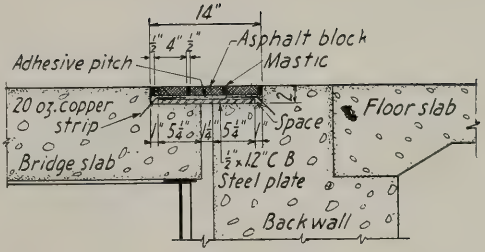


FIG. 7 EXPANSION JOINT FOR HIGHWAY SLABS AT BACK WALL

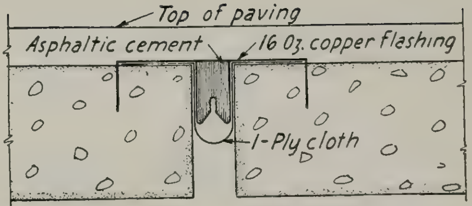


FIG. 8 EXPANSION JOINT DEVICE, SLAB TYPE

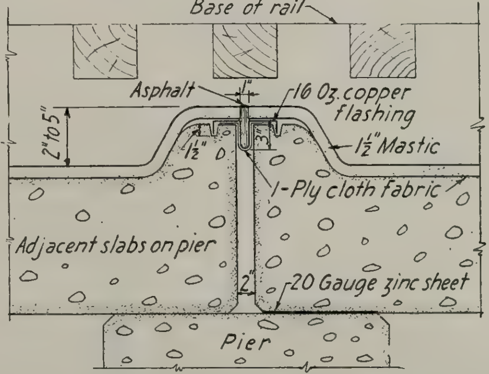


FIG. 9 EXPANSION JOINT DEVICE, ELASTIC FILLER

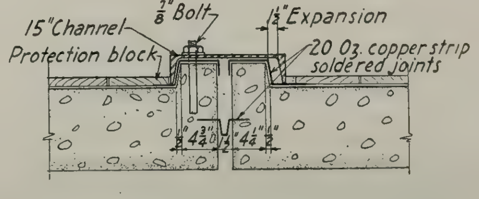


FIG. 10 TRANSVERSE EXPANSION JOINT DECK SLAB ON GIRDERS

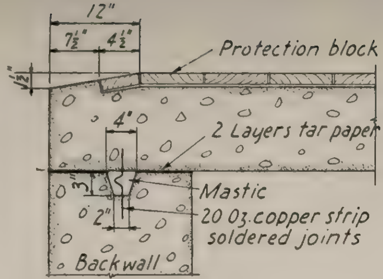


FIG. 11 SLAB JOINT AT BACKWALL

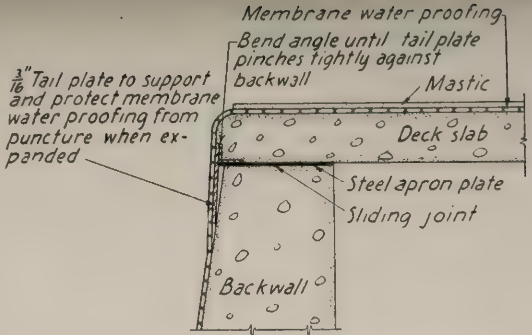

Membrane water proofing
Bend angle until tail plate pinches tightly against backwall
3/16" Tail plate to support and protect membrane water proofing from puncture when expanded
Mastic
Deck slab
Steel apron plate
Sliding joint
Backwall

FIG. 12 HORIZONTAL JOINT OVER BACKWALL, WATER PROOFED DECK

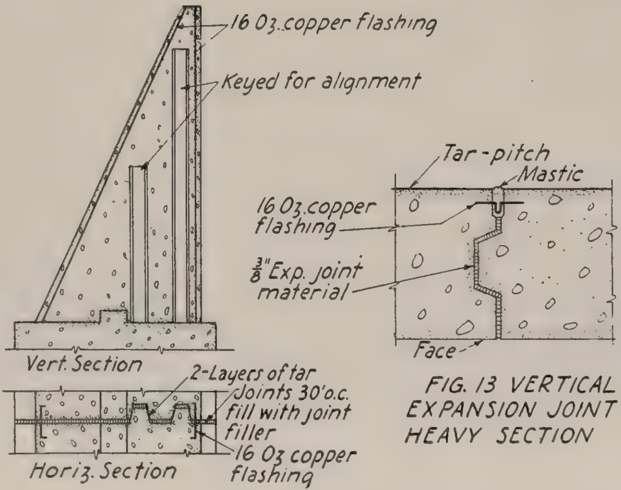


FIG. 13 VERTICAL EXPANSION JOINT HEAVY SECTION

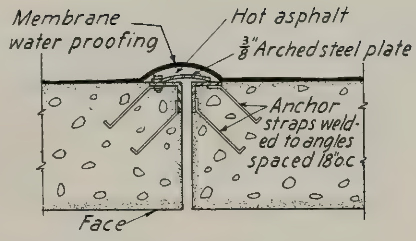


FIG 14 VERTICAL OPEN EXPANSION JOINT PROTECTED ON BACK

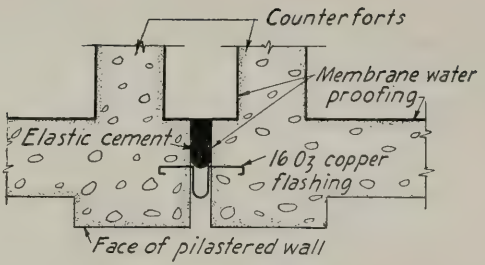


FIG 15 EXPOSED JOINT PILASTERED WALL

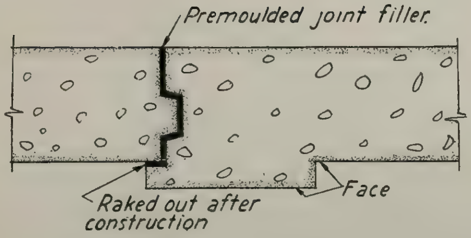


FIG. 16 JOINT HIDDEN BEHIND PILASTER

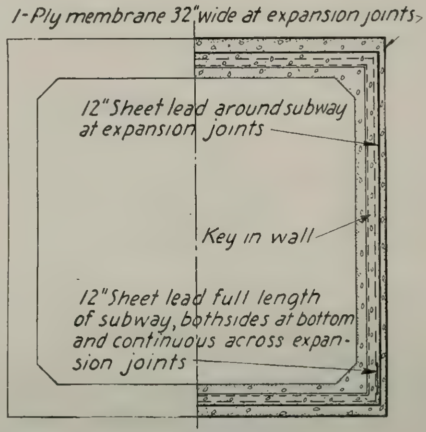

1-Ply membrane 32" wide at expansion joints
12" Sheet lead around subway at expansion joints
Key in wall
12" Sheet lead full length of subway, both sides at bottom and continuous across expansion joints

FIG. 17 PEDESTRIAN SUBWAY

REPORT OF SPECIAL COMMITTEE ON WATERPROOFING OF RAILWAY STRUCTURES

J. A. Lahmer, *Chairman;*	F. R. Judd,	F. P. Turner,
G. E. Boyd,	G. E. Robinson,	R. A. Van Ness,
A. C. Copland,	G. A. Rodman,	L. W. Walter,
O. F. Dalstrom,	I. L. Simmons,	H. T. Welty,
A. C. Irwin,	A. B. Stone,	C. A. Whipple,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully presents herewith its report on the following subjects:

(1) Revision of Manual.

Change Section 61 of Specifications for Membrane Waterproofing to read:

"61. At construction joints the primer shall be omitted for a width of 9 in. on each side of joint and a strip of insulating paper 18 in. wide laid thereon before waterproofing is applied."

(2) Principles governing the use of waterproofing or dampproofing of railway structures (Appendix A).

This subject has been given further study and report presented last year (with minor changes) is resubmitted with recommendation that it be adopted and included in the Manual.

(3) Waterproofing and dampproofing as applied to existing railway structures (Appendix B).

Submitted as information with recommendation that subject be discontinued.

(4) Specifications for Materials and Application of Bituminous Emulsions (Appendix C).

Tentative specifications for asphalt emulsion of clay pipe and coal-tar emulsion of soap type have been prepared and are submitted as information. Criticism is invited. Specifications for other types of emulsion and for cut-back asphalt and cut-back coal-tar are receiving consideration.

Special Committee on Waterproofing of Railway Structures,
J. A. Lahmer, *Chairman.*

Appendix A

(2) PRINCIPLES GOVERNING THE WATERPROOFING OR DAMPPROOFING OF RAILWAY STRUCTURES

O. F. Dalstrom, Chairman, Sub-Committee; A. C. Irwin, G. E. Robinson, G. A. Rodman, I. L. Simmons, C. A. Whipple.

Waterproofing

1. Adequate and effective drainage should be provided to remove water from the waterproofed surface if practicable.

2. Where the range of temperature varies from above freezing to below freezing, the disintegrating effect of frost action on water-saturated masonry must be recognized and adequately guarded against.

Where the temperature does not fall below freezing, the destructive effects of water penetration, but not permeation, by water free from corrosive elements are small. In cases of the passage of small quantities of water through parts of structures not subject

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Bulletin 384, February, 1936.

to freezing temperatures, waterproofing should be provided only as required by appearance of surfaces or use of structure.

3. Waterproofing should not be applied to the face of masonry subject to freezing and thawing, where water reaches that face through the masonry.

4. The materials for waterproofing and the methods of application should be such as to insure that the waterproofing will be retained by bond, anchorage or other adequate means, in its original position as applied to the surface to be waterproofed.

5. Where waterproofing is subject to possible injury from abrasion, pressure, puncture or otherwise, it should be protected with a substantial covering.

6. Waterproofing should be applied where economically justified, considering the use and probable life of the structure and the cost of obtaining adequate watertightness by design and construction.

7. The type of waterproofing should be determined by the use and probable life of the structure, and the cost of renewal of the waterproofing:

(A) Waterproofing of the most durable and effective type should be used on permanent structures:

(a) In locations subject to water or other liquids under a hydrostatic head;
(b) Where repair or renewal is impracticable or prohibitive in cost;
(c) Where certainty of watertightness must be had because of heavy damage if water enters.

(B) Waterproofing specially designed for the purpose should be used where the structure must be protected against liquids containing corrosive and/or disintegrating substances.

8. A waterproofing membrane on the surface adjacent to the water source is the most effective externally applied waterproofing, but difficulties of application and prohibitive cost may sometimes make consideration of some other method advisable.

9. Surface applications on the inner faces of walls for the purpose of waterproofing against external pressure must derive their effectiveness from bond with the masonry or from closing the surface pores. Such applications can generally be considered effective only to prevent seepage under little or no head. Such coatings must be insoluble and unaffected by dampness.

Dampproofing

1. Dampproofing is effective in preventing the accumulation of surface moisture from condensation only in proportion to its temperature-insulating value.

2. Dampproofing will probably not be effective where masonry is subject to moisture saturation accompanied by cycles of freezing and thawing.

3. Ordinary dampproofing is not effective against cracks or openings through the masonry.

4. A frequent fault of one-coat dampproofing is failure to produce a continuous covering free from pin holes. This should be considered in deciding upon the number of coats that should be applied.

5. The purpose and character of dampproofing are not such as to require special protection or covering. Where protection or covering is necessary, the conditions will usually warrant the use of waterproofing.

6. A prime requisite of dampproof covering is that it shall stay in place. Bond with the surface is therefore essential.

7. The selection of materials for dampproofing must include consideration of the effect of extremes of temperature, the effect of the sun's rays, and the physical and chemical effects of the liquid to which they will be subjected.

SPECIFIC CASES

Abutments, Piers and Retaining Walls

1. On the assumption that effective drainage has been provided, waterproofing on the back of an abutment or retaining wall is generally not necessary, but dampproofing should be provided above the footings. Where it is desired to prevent the passage of water, expansion joints and construction joints should be sealed by metal dams or other effective means.

Short Single-Span Arches and Box Culverts

2. Short single-span arches and box culverts should be dampproofed on the surfaces in contact with the fill.

Pedestrian Subways

3. Pedestrian subways should be waterproofed.

Arches—Long Single Span and Multiple Span with Spandrel Fill

4. Long single-span arches and arches of multiple span with spandrel fill should be fully waterproofed on all surfaces in contact with the fill, including the parapets.

Precast Slabs for Bridge Decks and Floors

5. (A) Not over Streets or Pedestrian Subways—
    - (a) The top surface of slabs and the backs of parapets should be dampproofed when used on reinforced concrete pile bents with cast-in-place reinforced concrete caps, or on concrete piers or abutments.
    - (b) The top surface of slabs and the backs of parapets should be waterproofed or dampproofed when set on steel floorbeams, stringers or girders.
    - (c) Joints should be calked with oakum up to within 2 or 3 inches of tops of slabs, the calking extending downward as far as necessary to close the joints against the flow of the waterproofing material used to fill the joints. The space above this oakum packing shall then be filled to the top surface of the slab with plastic joint-filling material.

   (B) Over Streets or Pedestrian Subways—

   In addition to treatment of joints as in paragraph (c) next above, the top surface of slabs and the backs of parapets should be waterproofed.

Cast-In-Place Concrete Bridge Decks or Floors

6. (A) The top surface of slabs and the backs of parapets should be waterproofed or dampproofed and the construction joints closed with metal dams, where the slab is an integral part of the structure, as in rigid frames or girderless flat slabs, or where it is the main load-carrying element, as in simple or continuous slabs, provided it is sufficiently reinforced for both positive and negative moments.

   (B) When the slab is supported on steel beams, all construction joints should be closed with metal dams and membrane waterproofing applied.

Pump Pits for Subways and Basements

7. Pump pits should be waterproofed or dampproofed on all exterior surfaces.

Pipe Manholes and Pipe Tunnels

8. Pipe manholes and pipe tunnels should be dampproofed or waterproofed on all exterior surfaces.

Water Containers

9. The walls and floors of water containers, such as reservoirs and tanks, should be made of dense concrete to insure watertightness. Special attention should be given to the waterproofing of all joints.

Walls and Floors of Buildings

10. The walls and floors of all buildings subject to hydrostatic pressure should be waterproofed on pressure surfaces.

If not subject to hydrostatic pressure, all exterior walls should be dampproofed below ground.

Dampproofing should be applied to the back and top (under coping) of parapet walls and to the back and to the embedded surfaces of architectural masonry trim; also, to the inside of exterior masonry walls if plaster is to be applied without furring.

Special attention should be given to all joints and to places where pipes or other facilities pass through walls.

Platforms, Walkways and Roadways

11. Platforms, walkways and roadways over rooms or spaces used as adjuncts to buildings should be waterproofed.

Grain Elevator Pits and Similar Underground Structures

12. Grain elevator pits and similar underground structures should be made watertight by design and construction or waterproofed on the exterior.

Appendix B

(3) WATERPROOFING AND DAMPPROOFING AS APPLIED TO EXISTING RAILWAY STRUCTURES

A. C. Irwin, Chairman, Sub-Committee; F. R. Judd.

A questionnaire regarding methods employed for waterproofing and dampproofing existing railway structures was sent to Class I railroads, and answers received (which are abstracted below) cover such a wide range of conditions and treatment that it is not practicable to prepare rules or recommendations for such work, particularly as the remedies in many cases included the application of proprietary or patented material.

WATERPROOFING

1. Stations, Shops, Offices and Miscellaneous Buildings

(a) One Railroad Company reports waterproofing a passenger station basement as follows:

There was a steady seepage of water all over basement floor through the surface of the concrete, the cement finish of which appeared to be very poor.

At chimney base, water came through joints of brickwork. Joints were plugged with a preparation made of a bituminous compound, cement, litharge and oakum. Several cracks in brickwork were also plugged with this mixture and proved very satisfactory.

Floor surface was treated with a special cement filler, which penetrated the top surface and kept back the seepage, permitting an application of a permanent pliable oil.

Twenty-four hours later, places of severe seepage were given a coat of special bond paste. After 24 hours, a finish coat was applied made of 1 gallon of permanent pliable oil and 1½ lb. of cement.

After two weeks, two or three places seeped through. These were plugged with permanent pliable oil and cement and given another finish coat of permanent pliable oil and cement.

Basement was absolutely dry two months later and agent was well satisfied with results. The work was done by company forces.

(b) Another Company reports pits in shops, scale pits and basements were caulked and plastered inside with mortar mixed with a metallic or an accelerating preparation on small areas with rather small leaks and in other instances inside surfaces were shotcreted with a 50-50 mixture of neat cement and sodium silicate mixed with water on large areas with many leaks.

Concrete floors of basements have been broken down close to walls, excavated alongside and under walls and earth replaced with broken stone graded so that water would flow to drainage pipes.

Pits have been caulked on the inside with mortar made of Portland cement mixed with special liquid preparations.

Their recommendation is if size of job justifies that shotcreting with special mixture of neat cement be used.

If flow of water is extensive and at various points, it is advisable to concentrate flow in pipes placed in holes drilled in masonry, applying waterproofing over the whole area affected and leading flow into drainage system. Waterproofing need be only a thin coat over the whole area and add a layer of shotcrete of Portland cement and sand at least 4 inches thick mixed with water and reinforced with expanded metal for protection.

On comparatively small areas and where leaks are small, either a few or many of them scattered, caulk and plaster with metallic or bituminous preparations.

(c) One Company reports waterproofing a passenger station concrete basement by driving sheet piling of 2-inch "V" sheathing below lowest point and bracing it, excavating outside of walls and pumping continually (tidewater). Poured 4 inch floor slab and applied 5 ply specification felt and pitch to sheathing, thoroughly mopping and lapping each sheet 17 inches over preceding one. Lapped felt 10 inches over floor slab and reinforced all corners with two additional sheets. Set inside wall forms and poured concrete. Poured a second floor slab after removal of inside forms. The work was done by contract. Membrane waterproofing is recommended for this class of work.

(d) Basements and pits have been waterproofed by applying several plies of hot asphalt with fabric or asphalt felt on outside.

Usually membrane is not successful if piers, pilasters or angles are numerous.

Integral waterproofing is unsatisfactory because of construction joints in concrete.

Plaster or brush coat of metallic cement grout on inside is efficient for waterproofing, unless head is high, in which case membrane on the outside is necessary.

(e) An office building basement was waterproofed by applying a wash coat of cement grout and metallic and chemical mixtures on the inside.

(f) Leaks in the basement walls of a large office building were successfully stopped by drilling holes through the walls and pumping grouting material through them to the pressure side of the wall. The work was performed by a waterproofing company and has proved entirely satisfactory. The plaster coat method was considered, but could not be used in this case without removing a lot of piping and machinery.

2. Subways and Tunnels

(a) Tunnels have been waterproofed by drilling holes through roof and applying cement grout under pressure.

(b) In one instance, when the roof of a tunnel leaked badly and concrete disintegrated due to seepage and frost action, holes were drilled through the roof and pipes were inserted to take care of the water. All poor concrete was removed and replaced with shotcrete with very satisfactory results.

(c) In the case of a sub-track waiting, mail and baggage room, membrane waterproofing was used to replace copper expansion joints. The copper "V" strips were removed and 3 layers of membrane flashed into joints, filling up the pocket with granular cork and a soft asphalt mixture with 2 strips of copper lapping over the center of the joints and protecting the entire joint with 1½ inch cedar plank. This method was considered more desirable than trying to use copper "V" flashing, particularly at tee or cross joints.

The work was performed by contract. Membrane waterproofing is recommended for work of this kind.

(d) A tunnel was waterproofed by caulking cracks with a metallic preparation on the inside and then applying a metallic wash coat.

The work was performed by contract. The use of membrane is recommended for this kind of work.

(e) One Company reports tunnels plastered and caulked on the inside with mortar mixed with a metallic, bituminous or similar preparation on small areas and small leaks. Shotcreted outside with a 50-50 mixture of neat cement and sodium silicate mixed with water on large areas with many leaks.

The work was performed by Company forces. Shotcreting is recommended if the size of the job justifies.

3. Grain Bins and Elevators

(a) One Company reports repairing cracks in concrete grain bins with cement caulking, which was successful, except the caulking of moving joints. Membrane is recommended for this class of work.

(b) Basement walls of a grain elevator that were porous and cracked were waterproofed with a metallic coating applied inside, according to method recommended in manufacturer's instructions. When applied by the waterproofing company selling this service, the method was a success. When done by railroad forces, it was not watertight.

The metallic coating method is recommended if workmen are experienced or instructed and supervised.

(c) Elevator bins and headhouse were waterproofed by thoroughly sand blasting the walls and then giving them a metallic waterproofing binder coat and finished with two cement slush coats after repairing the defective construction seams.

This work was done by contract and this class of waterproofing is recommended.

(d) On account of damage from fire, it was necessary to waterproof all outside surfaces of storage tanks above ground to prevent leaks. They occurred at joints and cracks and other locations where concrete was not in good condition. Defective concrete was removed, surfaces treated with a metallic coating and then holes filled in with concrete. All outside surfaces were thoroughly cleaned and five coats of metallic waterproofing and one coat of waterproofing mortar was applied.

The work was done by contract. The metallic coating processes are considered satisfactory.

4. Bridge Decks

(a) After failure of membrane waterproofing on a steel bridge floor, consisting of three layers of felt, four layers of asphalt and a 3 inch cement topping, the membrane was replaced with one consisting of cotton fabric, which is giving satisfaction.

(b) Concrete bridge floor slabs, 30 inches thick, not waterproofed and carrying railroad traffic, developed leaks through many joints and porous places in slabs.

Pipes were grouted in at points of leakage on underside of slabs and patented solution was forced into voids under high pressure. Material used was insoluble in water and treatment was successful.

Joints were protected with copper flashing arranged to throw water to weep holes placed at frequent intervals.

This class of work has been performed by both Company forces and contract. Membrane waterproofing with cotton fabric is recommended for this class of work.

(c) On a station platform adjacent to a bridge, water leaked through joints and cracks in the concrete platforms. The joints and cracks were sealed with a liquid waterproofing plaster coat applied on top by Company forces.

Membrane waterproofing with protection coat is recommended for this class of work.

(d) One Company reports waterproofing bridge decks with membrane, consisting of four layers of asphalt treated felt, one middle layer of asphalt treated cotton fabric and six moppings of asphalt. They recommend membrane as above for bridges, but for pits, they use bituminous emulsions or accelerating mediums with waterproof steel lining embedded in concrete.

5. Coaling Stations

(a) Pits and bucket wells have been waterproofed with a metallic coating on the inside.

It is recommended that membrane and metallic coating processes be used.

(b) One Company reports coal chute pits waterproofed by metallic coatings applied inside according to directions of manufacturer and this method when so applied is recommended. It was not successful when applied by inexperienced railroad forces.

6. Sumps and Reservoirs

(a) Leaks in a concrete reservoir were stopped by plastering entire interior with mortar made of one part cement and three parts sharp sand, hand laid to thickness of ½ inch.

The work was done by Company forces and this class of waterproofing is recommended.

(b) Leaks in a concrete sump were stopped by applying two coats of patented trade preparation, partly by spraying and partly by brush.

DAMPPROOFING

1. Stations, Shops, Offices and Miscellaneous Buildings

(a) A warehouse of concrete construction with brick spandrels and panels leaked at the junction of concrete and brickwork. Pointing up the joints on the outside did no good. The condition was corrected by the use of a bituminous emulsion, which was applied as a ribbon-like strip along the joints on the inside in three applications. The first coat was cut back 20 per cent with water and the second and third coats were applied full strength.

(b) A concrete retaining wall forming the wall of building was successfully dampproofed by excavating along the back of wall and coating the back of wall with a mastic waterproof mixture.

(c) Seepage through the brick walls of a power house was corrected by raking out and repointing the joints.

(d) Seepage through brick freight house walls was stopped by applying a coat of paraffin oil on the outside of the walls. While fairly satisfactory, it is expected to be temporary and short lived.

(e) Brick walls of an engine house were coated with a bituminous coating on the inside and most of the leakage was stopped.

(f) Seepage through walls of cast concrete transformer houses was stopped by a coat of paraffin oil applied on the outside.

(g) Leaks through the walls of a concrete block record house during heavy rains were stopped by applying on the outside a brush coat of mastic.

(h) Porous and leaky roof and walls of a corrugated asbestos building were corrected by a brush coat of asphalt fiber roof coating.

(i) A Company reports cellar walls were dampproofed with a metallic coating and a cement wash applied on the inside of the walls, but that bituminous coatings are recommended for this class of work.

(j) Dampproofing walls of hollow tile with a stucco outside finish by using a wash coat of special liquid waterproofing is reported as giving good results.

(k) A concrete wall plastered on the inside was dampproofed by applying a wash coat of bituminous emulsion applied on the outside of the wall.

(l) It is reported that brick walls have been dampproofed by a treatment consisting of pointing joints with cement mortar and coating the wall with special liquid waterproofing.

(m) It is reported that cellar walls have been treated by applying a neat cement inside mixed with a special liquid preparation. It is recommended that such walls be finished with plaster and caulking of bituminous, metallic or accelerating compounds or similar preparations.

(n) Passenger and freight stations of stucco on brick and concrete walls, also brick curtain walls of concrete frame buildings, were dampproofed with liquid integral waterproofing added to stucco and cement paint or paint with waterproofing compound, or pitch, applied to inside of walls and to parapet walls. It is recommended that dampproofing be applied with pressure.

(o) On the concrete roof of an oil house which leaked, various paints were tried without success. It was found that by coating with aluminum paint, the leaks were completely stopped and this method is recommended for similar work.

(p) The brick walls of a freight depot were successfully dampproofed with a bituminous emulsion applied on the inside. The work was done by contract.

(q) The brick walls of a store house were successfully dampproofed with a wash coat of special liquid waterproofing applied to the outside of the walls.

(r) The porous brick walls of a warehouse were coated with a transparent liquid dampproofing containing paraffin. This is considered a temporary expedient and has to be repeated.

(s) A thin paste of cement and water has been applied to outside of concrete block walls of a Y.M.C.A. building with good results.

(t) A station platform forming a freight house roof was dampproofed by filling cracks in the platform with asphalt emulsion and the entire surface covered with asphalt mastic ¼ inch thick applied on the underside.

2. Subways and Tunnels

(a) Abutments are dampproofed by applying two coats of asphalt emulsion on the back of the walls.

(b) A subway was dampproofed by applying neat cement mixed with a special liquid preparation on the inside surfaces. It is recommended that caulking and plastering with metallic, bituminous or accelerating mediums, or similar preparations, be used for this class of work.

3. Grain Bins and Elevators

(a) Grain elevator bins were successfully dampproofed as follows: All disintegrating and loose concrete was removed, cracks and honeycomb surface completely filled and restored with cement mortar, using cement gun where extended surfaces were affected.

The outside surface of the elevator was then treated with a metallic coating system.

Appendix C

(4) SPECIFICATIONS FOR BITUMINOUS EMULSIONS

F. P. Turner, Chairman, Sub-Committee; G. E. Robinson, G. A. Rodman, L. W. Walter, H. T. Welty.

MATERIAL

Asphalt Emulsion (Clay Type) shall be a steam refined type of asphalt similar to that specified in Section 6 of Specifications for Membrane Waterproofing as printed in the Manual (except that the softening point shall be between 90° Fahr. and 120° Fahr. and penetration at 77° Fahr. shall be not less than 100) thoroughly dispersed in water by means of a suitable dispersing agent. Emulsion as received shall conform to the following analysis by volume:

Bitumen	Min. 58 per cent, plus or minus 2 per cent
Non-volatilizing matter	Max. 3 per cent
Water	Max. 40 per cent, plus or minus 2 per cent

Coal Tar Emulsion (Soap Type) shall contain a coal tar base thoroughly dispersed in water by means of a suitable dispersing agent.

The emulsion shall contain not less than 30 per cent or more than 40 per cent of water by volume.

The specific gravity at 77° Fahr. of the emulsion shall be not less than 1.05.

The emulsion shall have an oven evaporation loss, 20 grams in a 2 oz. seamless ointment box (2½ in. diameter and 13/16 in. deep, Philadelphia style, flat bottom), 3 hours at 220° Fahr. of not more than 40 per cent.

The residue from the foregoing evaporation test shall have the following characteristics:

(a) Specific Gravity at 77° Fahr.	1.10 Min.
(b) Float test at 112° Fahr.	50 to 150 seconds
(c) Ash	2 per cent Maximum
(d) Insoluble in carbon disulphide	5 per cent to 15 per cent

General Requirements.—After the dried film of emulsion is in service it shall permanently resist reemulsification.

The reaction of emulsion to litmus paper shall not be acid.

The emulsifying process shall not seriously affect the elasticity, pliability, ductility, viscosity or other essential properties inherent in the original bitumen.

Only alcohol shall be introduced into emulsion to lower freezing point.

The emulsion shall not clot after indefinite dilution in water.

The bituminous particles shall remain in suspension until the water vehicle has evaporated.

When stored in a filled steel or iron closed container, the emulsion shall not deposit free bitumen for a period of at least 60 days after delivery.

When coated on a polished steel panel to a thickness of 1/16-in. to ⅛-in. and allowed to dry for 48 hours at a temperature of 77° Fahr. in air having a humidity of approximately 50 per cent the emulsion after immersion in water at 77° Fahr. for seven days shall retain its bond to the surface and its tenacity of body.

When coated on a polished steel panel to a thickness of 1/16-in. to ⅛-in. and allowed to dry for 48 hours at a temperature of 77° Fahr. in air having a humidity of approximately 50 per cent, it shall not be affected by immersion for a period of seven days in a saline or other alkaline (except hydroxides) solutions of any concentration, or in a 10 per cent acid solution.

The consistency and body of the emulsion shall be such that it can be readily applied with a brush, to a clean sheet-metal surface, in a single coat to a uniform thickness at the rate of one gallon per 125 square feet of surface.

When specified, asbestos fiber equal to 5 per cent to 7 per cent of weight of bitumen shall be incorporated mechanically by the manufacturer in the emulsion in order to provide a stronger film.

Inspection and Tests.—Except as otherwise provided, materials shall be sampled and tested for the specified properties by the current methods recommended by the American Society for Testing Materials.

The acceptance of any materials by the Inspector shall not be a bar to their subsequent rejection if found defective. Rejected materials shall be replaced promptly by the manufacturer.

All emulsions shall be delivered at job site not less than three weeks before they are to be applied, in order that they may be tested and analyzed, and shall be in original containers bearing brand of manufacturer. They shall be stored and handled in such manner as to prevent damage by weather conditions, to prevent deterioration and to prevent intrusion of any foreign matter. Any damaged or deteriorated material shall be immediately removed from site of work.

APPLICATION

Preparation of Surface.—Surfaces upon which bituminous emulsion is to be applied must be cleaned of dirt, dust or other loose particles. Oils or grease, when present, must first be removed by proper solvents and the surface must then be washed with clean water. Old walls must be scrubbed with a wire brush and if necessary a chisel or scraper shall be used in order to produce a clean surface upon which the emulsion may be spread. Rust or mill scale must be removed from metal surfaces by the use of wire brush or sand blast.

Where cracks appear in walls, or where walls have disintegrated or are honeycombed, the surface must be repaired in accordance with AREA Specifications for repairing deteriorating concrete.

Method of Application.—The emulsion shall be applied either by means of spray or a substantial four inch bristle brush, or mopped on with a three knot brush. Emulsion containing asbestos fiber shall be applied by means of a brush or trowel. When applied with a trowel, the surface on which applied shall first be given a priming coat of emulsion without fiber.

Each coat shall be allowed to become thoroughly dry before the next coat is applied. After a coat has dried completely, the dry finger tip firmly pressed into the film and withdrawn shall not cause a clean separation between the bituminous emulsion and the surface upon which it has been applied.

When used on concrete, the emulsion shall preferably be applied immediately after the forms have been removed and in no case to a dry masonry surface.

Emulsion shall generally be used as received and shall be thoroughly stirred before being applied. If necessary to thin the emulsion, this shall be done by the addition of water only.

At the junction between horizontal and vertical surfaces, special treatment, such as waterproofing membrane, shall be provided if necessary.

Amount of Emulsion to be Used.—The emulsion shall be applied in not less than two coats, the first coat to be applied at rate of not more than 1½ gallons per square.

It is essential that there be complete coverage of the area to be dampproofed and that the film of emulsified bitumen shall be intact over all, without bare spots, blisters or pin holes.

When emulsion without fiber is used, not less than a total of four (4) gallons per 100 square feet, for two coats, shall be applied.

When emulsion containing fiber is used, the first coat shall be non-fibrated emulsion applied at rate of not more than 1½ gallons per square and the second coat shall be fibrated emulsion applied at rate of not less than 3½ gallons per square.

Temperature.—The emulsion must not be applied to frozen surfaces or allowed to freeze in the containers, or after application, until it has set through evaporation of water. Emulsion which has been frozen must not be used. The emulsion shall not be applied at temperatures below 45° Fahr., and sufficient time must be allowed for emulsion to set before temperature drops below 45° Fahr.

REPORT OF COMMITTEE VII—WOOD BRIDGES AND TRESTLES

H. AUSTILL, *Chairman;*	C. S. JOHNSON,	F. H. CRAMER, *Vice-Chairman;*
H. M. CHURCH,	W. N. KEENEY,	W. R. ROOF,
G. M. CORNELL,	J. A. NEWLIN,	W. J. RYAN,
S. F. GREAR,	W. A. OLIVER,	D. W. SMITH,
R. W. GUSTAFSON,	W. L. PEOPLES,	A. T. UPSON,
R. P. HART,	G. W. REAR,	W. R. WILSON,
W. E. HAWLEY,	ARTHUR RIDGWAY,	
C. J. HOGUE,	H. T. RIGHTS,	*Committee.*

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of Manual (Appendix A).

(2) Simplification of grading rules and classification of timber for railway uses, collaborating with other organizations concerned (Appendix B). Partially complete, with recommended conclusions for publication in the Manual.

(3) Overhead wood or combination wood and metal highway bridges, collaborating with Committee XV—Iron and Steel Structures (Appendix C). Partially complete, with recommended conclusions for publication in the Manual.

(4) Design of wood trestles for heavy loadings (Appendix D). Partially complete, with recommended conclusions for publication in the Manual.

(5) Bearing power of wood piles, with recommendation as to methods of determination, collaborating with Committee VIII—Masonry (Appendix E). Progress report.

(6) Recommended relationships between the energy of hammer and the weight or mass of pile for proper pile driving, to include concrete piles, collaborating with Committee VIII—Masonry (Appendix F). Progress report.

(7) Improved design of wood structures to give longer life with lower cost of maintenance. Progress in study—no report.

(8) Design of and specifications for washers, separators, cap-stringer straps and other wood bridge and trestle fastenings (Appendix G). Progress report.

(9) Review specifications for overhead highway bridges of the Association of State Highway Officials insofar as they relate to wood construction (Appendix H). Progress report.

THE COMMITTEE ON WOOD BRIDGES AND TRESTLES,
H. AUSTILL, *Chairman.*

Bulletin 384, February, 1936.

Appendix A

(1) REVISION OF MANUAL

D. W. Smith, Chairman, Sub-Committee; F. H. Cramer, W. E. Hawley, Arthur Ridgway.

General

For Wooden Bridges and Trestles Section of the 1929 Manual:

Substitute "wood" for "wooden" wherever the term appears in the Manual.

Substitute "framed" for "frame" wherever the term appears in the Manual.

Substitute "ballasted deck" for "ballast deck" wherever the term appears in the Manual.

Page 449

Add "Skew.—Having an axis at any other angle than right."

Substitute "Helper Stringer" for "Jack Stringer".

Under "Sway Brace" substitute "a" for "the" before "bent".

Page 450

Add definition "Cap-Stringer Strap.—A piece of round, square, or structural shape iron or steel, either straight or bent, used to fasten stringers to a cap by means of horizontal bolts without the use of drift bolts."

Drift Bolt.—Change definition to "A piece of round or square metal with or without head or point and of specified length, driven as a spike."

"Packing Spool or Separator"—delete.

Page 456

Add to accompany the Economy Curves the explanation and examples which were originally published with them by the late W. H. Hoyt, pages 290 and 291, Part 2, Vol. 19, 1918, as follows:

"Economy Curves (Plate A)

"The formula for these curves is given with the curves. By assuming that n and m have a fixed ratio and using various life periods, it is possible to calculate values of f for each ratio of life periods and different lengths of life. By plotting these values of f and joining points calculated for the same ratio of life period, we get curves showing values of f for any life period within the limits of the curves. For convenience, those of even life ratio were plotted. For any fractional ratio of life period values of f can be found approximately close by interpolation between the appropriate curves. The curves start at zero life and ratios of cost equal to the ratio of life period and approach the ratio one as the life periods lengthen until at infinity $f =$ one, irrespective of the ratio of cost at the start. The curves are calculated with interest rate at 6 per cent, but the principle would be the same whether we used 3 per cent, 4 per cent, 5 per cent or 6 per cent, except that the higher the rate the more rapidly do the curves fall to the ratio one.

"Example:—A tie lasts ten years, how much are we justified in spending for a treated tie if it will last twenty years because of treatment? Entering the diagram at 10 at the bottom, carrying our eye up to curve of ratio 2 and reading from the scale of ordinates at the left, we find ratio of cost equals 1.55, or if our untreated tie costs 60 cents a treated tie should not cost over 1.55 times 60, or 93 cents. If we spend more than 93 cents we must obtain longer life than double or some other advantage must accrue to the roadbed.

"From these curves we can read off by interpolation what life we must get from the more expensive material with a given ratio of first cost.

"Example:—Wood lasts 10 years and steel may cost twice as much to accomplish the same ends. Entering the diagram at the ratio 2 at the left and noting the intersection with the 10-year life line, it is seen that the intersection lies about three-quarters of the distance between the three and four curves or the steel must last 3.75 times as long as the wood or 37.5 years.

"By a study of the curves it will be seen that a larger ratio of first cost is justified for short life structures than for long life structures even if the ratios of life periods are the same.

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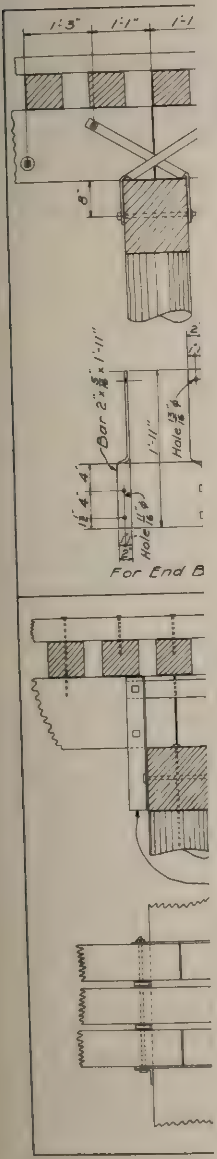

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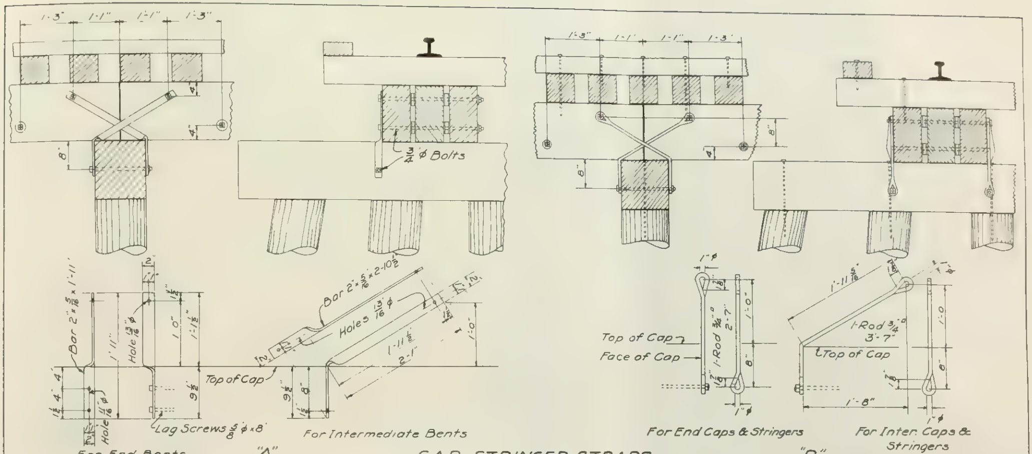
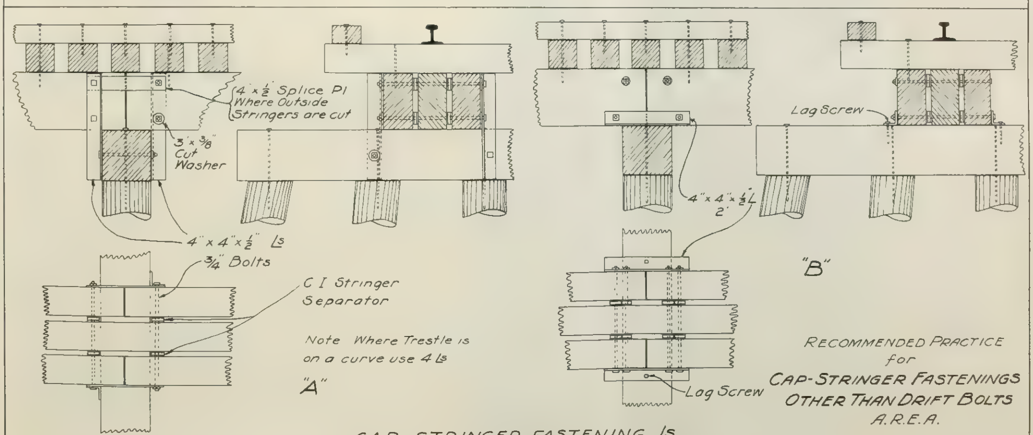
Cap-Stringer Straps shall be made of wrought iron or steel and shall be shaped as called for on the plans.



CAP-STRINGER STRAPS



CAP-STRINGER FASTENING Ls.

RECOMMENDED PRACTICE
for
CAP-STRINGER FASTENINGS
OTHER THAN DRIFT BOLTS
A.R.E.A.

"Example:—A softwood floor with a life of five years and a hardwood floor of 10-year life we find on the curve 2 that we are justified in spending up to 1.75 times the cost of the softwood floor for the hardwood. With a hardwood floor of 10-year life and a concrete floor of 20-year life we can spend up to only 1.55 times the cost of the hardwood.

"From this principle it will be seen that every additional year which we can add to the life of the lesser cost structure lowers the ratio of justified cost of a longer life structure, even though the longer life structure does last the same ratio of life. For example: Treated timber with a life of 25 years and steel of 50 years have a justified cost ratio of only 1.23 and even if we were to get infinite life from the steel only a cost ratio of 1.30 is allowable. This does not prove that steel should not be used, but indicates that where steel is used some other important factor such as maintenance or fire hazard must be the basis for spending a greater amount."

Page 458

COMPARATIVE MERITS OF CREOSOTED TIMBER BALLASTED DECK AND REINFORCED CONCRETE BALLASTED DECK TRESTLES

Paragraph 1—Change last sentence to read "yet due to the nature of the material used the reinforced concrete trestle has an advantage".

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VALUE OF TREATED TIMBERS IN WOOD BRIDGES AND TRESTLES

Paragraph 2—Change second sentence to read "If it is necessary to cut the surfaces after treatment, or if they become damaged, they should have several coats of hot creosote applied to protect them."

BEST METHOD OF FIREPROOFING WOOD BRIDGES AND TRESTLES

Paragraph 1—Substitute "fire" for "fires" in last line.

Paragraph 2—Change last two lines to read "otherwise, by covering the deck or the stringers and caps with rust-resisting sheet metal."

Page 462

Revise Trestle Plans to show two bolts in end connections of sash and sway braces to piles.

Add to list of plans:—Alternate cap-stringer fastenings.

Add drawing "Recommended Practice for Cap-Stringer Fastenings other than Drift Bolts."

Page 467

SPECIFICATIONS FOR METAL DETAILS USED IN WOOD BRIDGES AND TRESTLES

Paragraph 2—Substitute, "Steel shall conform to Specifications for Structural Steel as given under 'Iron and Steel Structures' ".

Paragraph 3—Substitute, "Except where chilled iron is specified castings shall conform to Specifications for Light Castings under 'Iron and Steel Structures' ".

Page 468

Bolts—delete.

Drift Bolts—delete.

Add—**Cap-Stringer Straps**

Cap-Stringer Straps shall be made of wrought iron or steel and shall be shaped as called for on the plans.

Page 469

Substitute the following:

SPECIFICATIONS FOR WOOD PILES

FIRST-CLASS PILES

MATERIAL

Kinds of Wood

1. The following kinds of wood suitable for piling are in common use: cedars, chestnut, cypress, Douglas fir, larch, oaks, pines, spruces, tamarack. Other kinds will not be accepted unless specifically ordered.

2. Piles for use after preservative treatment shall be termed sap piles and be so designated on the order for them.

PHYSICAL REQUIREMENTS

General Quality

3. Except as hereinafter provided, all piles shall be free from any defects which may impair their strength or durability as piling, such as decay, splits, twist of grain exceeding one-half of the circumference in any twenty feet of length or shake more than one-third of the average diameter of pile. The maximum diameter of a knot shall not exceed 4 in. nor one-third the least diameter of the pile section where it occurs. Knots in clusters or in groups shall not be permitted. Holes shall not exceed 1½ in. in diameter or be deeper than 1/5 of the diameter of the pile where the hole occurs. Numerous holes or small holes in groups shall not be permitted.

Decay

4. Cedar and cypress piles may have a pipe or stump rot hole not more than 1½ in. in average diameter. Cypress piles may have "peck" up to the limitations as to holes.

Close Grain

5. If close grain is specified for softwood piles, they shall show on the butt end not less than six annual rings per inch, measured radially over the outer three inches of the cross-section. Douglas fir and southern pine averaging from five to six annual rings per inch shall be accepted as the equivalent of close grain if having one-third or more summerwood.

Resistance to Decay

6. Piles for use without preservative treatment shall have as little sapwood as possible.

7. Piles for use with preservative treatment shall have as much sapwood as possible; in southern pine a sap ring of not less than 1½ in. and in Douglas fir of not less than 1 in. at the butt end.

SECOND-CLASS PILES

8. Piles for foundations that will always be completely submerged, and piles for cofferdams, falsework and sundry temporary work may be of any sound timber that will stand driving, and need not be peeled. They shall be free from any defects which may impair their strength as piling, such as decay, splits, twist of grain exceeding one-half the circumference in any twenty feet of length, large knots or holes, knots in clusters or groups or shake more than one-third the diameter of pile.

DESIGN

Dimensions

9. Piles shall have the following limiting dimensions.

FIRST-CLASS PILES

Southern Pine and Douglas Fir

(For Railway Bridges)

Length	Diameter 3 ft. from Butt Min.	 Max.	Diameter of Tip Min.
Under 40 ft.	14 in.	18 in.	10 in.
40 ft. to 50 ft. incl.	14 in.	18 in.	9 in.
51 ft. to 70 ft. incl.	14 in.	18 in.	8 in.
71 ft. to 90 ft. incl.	14 in.	20 in.	7 in.
Over 90 ft.	14 in.	20 in.	6 in.

(For Highway Bridges)

Under 40 ft.	12 in.	20 in.	8 in.
40 ft. to 50 ft. incl.	12 in.	20 in.	6 in.
51 ft. to 70 ft. incl.	12 in.	20 in.	6 in.
71 ft. to 90 ft. incl.	12 in.	20 in.	6 in.
Over 90 ft.	12 in.	20 in.	5 in.

Oak, Cypress and Chestnut

(For Railway Bridges)

Under 30 ft.	12 in. 14	18 in.	10 in.
30 ft. to 40 ft. incl.	12 in. "	18 in.	9 in.
Over 40 ft.	12 in. "	18 in.	8 in.

(For Highway Bridges)

Under 30 ft.	12 in. 14	20 in.	8 in.
30 ft. to 40 ft. incl.	12 in. "	20 in.	8 in.
Over 40 ft.	12 in.	20 in.	6 in.

Cedar

(For Railway Bridges)

Under 30 ft.	14 in.	22 in.	10 in.
30 ft. to 40 ft. incl.	14 in.	22 in.	9 in.
Over 40 ft.	14 in.	22 in.	8 in.

(For Highway Bridges)

Under 30 ft.	12 in.	22 in.	8 in.
30 ft. to 40 ft. incl.	12 in.	22 in.	8 in.
Over 40 ft.	12 in.	22 in.	7 in.

SECOND-CLASS PILES

40 ft. or less	12 in.	18 in.	8 in.
Over 40 ft.	12 in.	18 in.	6 in.

Tolerance

10. Dimensions given are minimum or maximum as stated, but a tolerance of ½ in. less in a given diameter will be allowed in not more than 25 per cent of the pieces of that diameter.

Length

11. All piles shall be furnished on order cut to any of the following lengths: 16 ft. to 40 ft. incl. in multiples of 2 ft., and over 40 ft. in multiples of 5 ft.

A variation of 6 in. in length will be allowed, but the average length in any shipment must be equal to, or greater than, the billed length.

Manufacture

12. Piles shall taper uniformly from the point of butt measurement to the tip.

13. Piles shall be free from short or reversed bends, and free from crooks greater than one-half the diameter of the pile at the middle of the bend. A line drawn from the center of the butt to the center of the tip shall lie within the body of the pile.

14. All knots and limbs shall be trimmed or smoothly cut flush with the surface of the pile. Ends must be cut square with axis of pile.

15. First-class piles shall be peeled smooth, clean and free of inner bark.

Inspection

Place

16. Piles will be inspected at suitable and convenient places satisfactory to the railway, at points of shipment or at destination. Piles will be inspected at points other than the railway's property whenever in the judgment of the railway there is sufficient number to warrant it; but the shipper shall provide accommodations for the inspector at the expense of the railway, while away from rail or steamer lines, and shall transport him from and to a railway station or steamer landing.

Manner

17. Inspectors will make a thorough examination of each pile. Each pile shall be judged independently without regard for the decisions on others in the same lot. Piles too muddied for ready examination will be rejected. Piles will be turned over as inspected, at the expense of the producer.

18. The diameter of a pile in cases where the tree is not exactly round, shall be ascertained by measuring the circumference and dividing it by 3.14.

Delivery

19. Piles delivered on the premises of a railway for inspection shall be stacked not less than 10 feet from the nearest rail of any track, or from highways, at suitable and convenient places, but not at public crossings, nor where they will interfere with the view of trainmen or of people approaching the railway. Piles shall be stacked in a secure manner in order that they shall not roll onto the railroad tracks or highway.

20. Each stack shall have fastened to it a tag on which is written the owner's name and address, the date when stacked, and the number of piles of each kind of wood in the stack. Piles for use without preservative treatment and those for preservative treatment shall be stacked separately.

21. All piles are at the owner's risk until accepted. All rejected piles shall be removed within one month after inspection, if required by the railway.

Shipment

22. Piles of different kinds of wood must be delivered in separate lots.

23. Piles forwarded in cars or vessels shall be separated therein according to kind, size and length if inspected before loading, or as may be stipulated in the contract or order for them.

Douglas Fir

Page 472:

Present Form

Douglas Fir	Pseudotsuga taxifolia (Coast type)
Red Fir	Pseudotsuga taxifolia (Intermountain type)
Red Fir	Pseudotsuga taxifolia (Rocky Mountain type)

Proposed Form

Douglas Fir	Pseudotsuga taxifolia (Coast Region)
Douglas Fir	Pseudotsuga taxifolia (Inland Region)
Douglas Fir	Pseudotsuga taxifolia (Rocky Mountain Region)

Pines

Page 473	*Present Form*
California White Pine	Pinus ponderosa and Pinus jeffreyi (Jeffrey pine)
	Proposed Form Delete California White Pine
	Present Form
Pondosa Pine	Pinus ponderosa
	Proposed Form
Ponderosa Pine	Pinus ponderosa and Pinus jeffreyi (Jeffrey pine)

Page 474

Add the following after *Pacific Yew:*

NOMENCLATURE OF COMMERCIAL DOMESTIC HARDWOODS

The following standard commercial names for lumber cut from the principal species, or groups of species, of domestic hardwoods shall be used in the construction of contracts and in the formulation of lumber-grading rules and the terms of purchase and sale of American standard lumber. Lumber cut from those species, or groups of species, marked with an asterisk (*) may be further designated as to region of production by the prefixes Appalachian, Northern, Southern, or Western:

Standard Commercial Name	*Botanical Name*
Red Alder	Alnus rubra A. rhombifolia (White)
Aspen	Populus tremuloides (Quaking) P. grandidentata (Largetooth)
*White Ash	Fraxinus americana F. biltmoreana (Biltmore White) F. pennsylvanica lanceolata (Green) F. pennsylvanica (Red) F. quadrangulata (Blue)
Black Ash	Fraxinus nigra
Oregon Ash	Fraxinus oregona
Basswood	Tilia glabra T. heterophylla (White)
Beech	Fagus grandifolia
Birch	Betula lutea (Yellow) B. lenta (Sweet) B. nigra (River)
Paper Birch	Betula papyrifera B. populifolia (Gray)
Red Birch	Heartwood of the above Birches
Alaska Birch	Betula kenaica
Buckeye	Aesculus octandra (Yellow) A. glabra (Ohio)
Butternut	Juglans cinerea
Catalpa	Catalpa speciosa
Cherry	Prunus serotina
*Chestnut	Castanea dentata C. pumila (Chinquapin)
Chinquapin	Castanopsis chrysophylla (Golden)
Coffeetree	Gymnocladus dioicus
*Cottonwood	Populus deltoides virginiana (Southern) P. heterophylla (Swamp) P. balsamifera (Balsam) P. deltoides (Eastern) P. sargentii

Standard Commercial Name	*Botanical Name*
*Black Cottonwood	Populus trichocarpa P. trichocarpa hastata (Northern Black) P. macdougalii (MacDougal) P. fremontii
Cucumber	Magnolia acuminata
Dogwood	Cornus florida
Pacific Dogwood	Cornus nuttallii
Rock Elm	Ulmus racemosa
Soft Elm	Ulmus americana (American) U. fulva (Slippery)
Black Gum	Nyssa sylvatica
Red Gum	Liquidambar styraciflua Heartwood only
Sap Gum	Liquidambar styraciflua Sapwood only
Hackberry	Celtis occidentalis C. laevigata (Sugarberry)
Hickory	Hicoria ovata (Shagbark) H. laciniosa (Bigleaf Shagbark) H. alba (Mockernut) H. glabra (Pignut) H. ovalis
Holly	Ilex opaca
Ironwood	Ostrya virginiana
Black Locust	Robinia pseudoacacia
Honey Locust	Gleditsia triacanthos
Lignumvitae	Guajacum sanctum
Madrone	Arbutus menziesii
Magnolia	Magnolia grandiflora (Evergreen) M. acuminata (Cucumber)
Mahogany	Swietenia mahagoni
Hard Maple	Acer saccharum (Sugar) A. nigrum (Black)
Oregon Maple	Acer macrophyllum
Soft Maple	Acer saccharinum (Silver) A. rubrum (Red)
White Maple	Acer saccharum Unstained sapwood
Mulberry	Morus rubra (Red)
Oregon Myrtle	Umbellularia californica
*Red Oak	Quercus borealis maxima Q. borealis Q. velutina (Black) Q. shumardii (Shumard) Q. texana (Texas red and Spanish) Q. palustris (Pin) Q. phellos (Willow) Q. laurifolia (Laurel) Q. rubra (Southern Red) Q. rubra pagodaefolia (Swamp red and Spanish) Q. nigra (Water) Q. ellipsoidalis (Jack) Q. coccinea (Scarlet) Q. marilandica (Blackjack) Q. kelloggii (California Black) Q. catesbaei (Turkey)
Tanbark Oak	Lithocarpus densiflora
*White Oak	Quercus alba Q. stellata (Post) Q. lyrata (Overcup) Q. bicolor (Swamp White) Q. muehlenbergii (Chinquapin) Q. garryana (Oregon White) Q. prinus (Swamp Chestnut)

Standard Commercial Name	*Botanical Name*
	Q. montana (Chestnut)
	Q. macrocarpa (Bur)
	Q. lobata (Valley White)
	Q. virginiana (Live)
	Q. douglasii (California blue)
	Q. utahensis (Rocky Mt. White)
	Q. emoryi (Emory)
	Q. arizonica (Arizona White)
	Q. oblongifolia (Mexican blue)
White (live) Oak	Quercus wislizenii (Highland Live)
	Q. agrifolia (Coast Live)
	Q. chrysolepis (Canyon Live)
Osage Orange	Toxylon pomiferum
Pecan	Hicora pecan
	H. cordiformis (Bitternut)
	H. cordiformis elongata (Bitternut)
Persimmon	Diospyros virginiana
Sassafras	Sassafras variifolum
Silverbell	Halesia carolina
Sycamore	Platanus occidentalis
Tupelo	Nyssa aquatica
Black Walnut	Juglans nigra
Willow	Salix nigra
*Yellow Poplar	Liriodendron tulipifera

SIZE CLASSIFICATION

Page 474

Add to the end of the third paragraph beginning "Dimension" the words "(See Note)", and at the bottom of the page add the following note:

"Note.—Dimension (planks and joists) to be used where working stresses are required should be considered and graded as structural material (See page ....)."

Page 488

Delete paragraphs 9 and 10, and substitute the following:

"9. With the grade classification in paragraphs 8, 46, 80, and 97 hereof as a basis and under the provisions with respect to grading, sizes, tally and inspection given in paragraphs 11 to 116, the various regional lumber manufacturers associations have published and apply detailed grading rules for their woods and products of Yard, Factory and Shop Lumber and of Shingles. These regional grading rules are recommended for use in the specification and purchase of the above kinds of forest products, providing the rules conform to the American Lumber Standards of nomenclature, definitions, and abbreviations, as here adopted by the American Railway Engineering Association."

Pages 494 to 497

Substitute the following:

SPECIFICATIONS FOR WOOD SHINGLES

(To supersede material on pages 494–497 of the 1929 Manual).

Materials

1. Shingles shall be manufactured from Western Red Cedar, Tidewater Red Cypress, or California Redwood.

Physical Requirements

2. Cross grain is not permitted in any No. 1 grade when it runs from one face of the shingle to the other within a longitudinal distance of 4 in. or less in any portion measured 12 in. from the butt. In any No. 2 or No. 3 grade badly cross-grained shingles are not permitted.

3. Diagonal grain is not permitted in any No. 1 grade when the grain diverges or slants 2 in. or more in width in 12 in. of length measured from the butt.

4. Color of wood is not a defect in any grade.

MANUFACTURE

Grades

5. The basic grades of shingles shall be No. 1, No. 2, and No. 3. The grade name shall be clearly marked on each bundle.

Sizes

6. Shingles are measured for thickness at the butt ends and designated according to the number of pieces necessary to constitute a specified unit of thickness. For example 4/2 indicates that 4 shingles measure 2 in., while 5/2¼ means that each 5 shingles measure 2¼ in. in thickness.

7. Standard sizes shall be 24 in. 4/2 in., 18 in. 5/2¼ in., and 16 in. 5/2 in., in either random-width or dimension shingles. 16 in. 6/2 in. shingles and 18 in. 5/2 in. shingles are not standard.

8. A variation of not to exceed 1 in. over or under in length is permitted in not to exceed 10 per cent of the shingles in any shipment.

9. No dimension shingle shall be more than one-fourth inch scant of the specified width when dry.

10. All No. 1 grade shingles must be uniform in thickness, well manufactured, with butts and one face smooth.

11. Shingles must be uniform in width; that is, possess parallel sides. In No. 1 grade of 16, 18, and 24 in. shingles, and in No. 2 grade of 16 and 18 in. shingles, one-fourth inch variation in width is permitted. In No. 2 grade of 24 in. shingles and in all No. 3 grades three-eighths inch variation in width is permitted.

12. A variation of 1 inch over and under in length is permitted in 10 per cent of the shingles in any shipment. Shingles cut from equalized blocks or from rebutted stock may be one-fourth inch less than the standard length.

13. In No. 1 grade not more than 10 per cent of the running (combined widths of shingles laid side by side) inches in any shipment may be less than 4 in. in width.

14. In No. 2 grade not more than 20 per cent of the running inches in any shipment may be less than 4 in. wide.

15. In No. 3 grade not more than 30 per cent of the running inches in any shipment may be less than 4 in. wide.

16. When knots are cut on an angle, the diameter of the knot is measured on the shortest dimension.

Random-Width Shingles

No. 1 Grade

24″–4/2″:

17. To be all edge grain, strictly clear, and contain no sapwood.

18. No shingles to be wider than 14 in. and none narrower than 4 in.

19. Bundles shall measure 6½ in. and 7 in. across butts when green and a minus tolerance of 3 per cent of the thickness of the bundle is allowable when dry.

20. Packed 13/14 courses to bundle, 4 bundles to the roofing square, based on a 7½-in. exposure; 3 bundles to the side wall square, based on a 10-in. exposure.

18″–5/2¼″:

21. To be all edge grain, strictly clear, and contain no sapwood.

22. No shingles to be wider than 14 in. and none narrower than 3 in.

23. Bundles shall measure 8⅛ in. across butts when green and a minus tolerance of 3 per cent of the thickness of the bundle is allowable when dry.

24. Packed 18/18 courses to the bundle, 4 bundles to the square, based on a 5½-in. exposure.

16″–5/2″:

25. To be all edge grain, strictly clear, and contain no sapwood.

26. No shingle to be wider than 14 in. and none narrower than 3 in.

27. Bundles shall measure 8 in. across butts when green and a minus tolerance of 3 per cent of the thickness of the bundle is allowable when dry.

28. Packed 20/20 courses to the bundle, 4 bundles to the square, based on a 5-in. exposure.

No. 2 Grade

24″–4/2″:

29. To be 16 in. clear or better, and measured from the butt may contain not to exceed a total of 1 in. of sapwood for the first 10 in.

30. Shims and feather tips not less than 20 in. long permitted.

31. Defects may consist of knots or knot holes up to 3 in. in diameter, small rot pockets or wormholes. Aggregate defects shall not exceed one-half the width of the shingle.

32. No shingles shall be wider than 14 in. and none narrower than 3 in.

33. Bundles shall average 6½ in. and 7 in. across butts when green and a minus tolerance of 3 per cent of the thickness of the bundle is allowable when dry.

34. Packed 13/14 courses to the bundle, 4 bundles to the roofing square, based on a 7½ in. exposure; 3 bundles to the side wall square, based on a 10-in. exposure.

18″–5/2¼″

35. To be 12 in. clear or better, and measured from the butt, may contain not to exceed a total of 1 in. of sapwood for the first 10 in.

36. Shims and feather tips not less than 16 in. long permitted.

37. Defects may consist of knots or knot holes up to 3 in. in diameter, small rot pockets, or wormholes. Aggregate defects shall not exceed one-half the width of the shingle.

38. No shingles to be wider than 14 in. and none narrower than 3 in.

39. Bundles shall average 8⅛ in. across butts when green and a minus tolerance of 3 per cent of the thickness of the bundle is allowable when dry.

40. Packed 18/18 courses to the bundle, 4 bundles to the square, based on a 5½-in. exposure.

16″–5/2″:

41. To be 12 in. clear or better, and measured from the butt, may contain not to exceed a total of 1 in. of sapwood for the first 10 in.

42. Shims and feather tips not permitted.

43. No shingles to be wider than 14 in. and none narrower than 3 in.

44. Defects may consist of knots or knot holes up to 2 in. in diameter, small rot pockets or wormholes. Aggregate defects shall not exceed one-half the width of the shingle.

45. Bundles shall measure 8 in. across butts when green and a minus tolerance of 3 per cent of the thickness of the bundle is allowable when dry.

46. Packed 20/20 courses to the bundle, 4 bundles to the square, based on a 5-in. exposure.

No. 3 Grade

24″–4/2″:

47. To be 10 in. clear or better and may contain sapwood. Shims and feather tips not less than 18 in. long permitted.

48. Defects may consist of knots or knot holes up to 3 in. in diameter, small rot pockets, or wormholes. Aggregate defects shall not exceed two-thirds the width of the shingle.

49. No shingle to be wider than 14 in. and none narrower than 3 in.

50. Bundles shall average 6¼ in. and 6¾ in. across the butts when green and a minus tolerance of 3 per cent of the thickness of the bundle is allowable when dry.

51. Packed 13/14 courses to the bundle, 4 bundles to the square, based on a 7½-in. exposure; 3 bundles to the square, based on a 10-in. exposure.

18″–5/2¼″:

52. To be 8 in. clear or better, sap permitted.

53. Shims and feather tips not less than 14 in. long permitted.

54. Defects may consist of knots or knot holes up to 3 in. in diameter, small rot pockets or wormholes. Aggregate defects shall not exceed two-thirds the width of the shingle.

55. No shingle to be wider than 14 in. and none narrower than 3 in.

56. Bundles shall average 7⅞ in. across butts when green and a minus tolerance of 3 per cent of the thickness of the bundle is allowable when dry.

57. Packed 18/18 courses to the bundle, 4 bundles to the square, based on a 5½-in. exposure.

16″–5/2″:

58. To be 8 in. clear or better and may contain sapwood.

59. Shims and feather tips not less than 14 in. long permitted.

60. No shingle to be wider than 14 in. and none narrower than 2½ in.

61. Defects may consist of knots or knot holes up to 3 in. in diameter, small rot pockets or wormholes. Aggregate defects shall not exceed two-thirds the width of the shingle.

62. Bundles shall average 7¾ in. across butts when green, and a minus tolerance of 3 per cent of the thickness of the bundle is allowable when dry.

63. Packed 20/20 courses to the bundle, 4 bundles to the square, based on a 5-in. exposure.

Dimension Shingles

No. 1 Grade

64. All shingles to be edge-grain, strictly clear, free from sapwood. No shingles shall be more than ¼-in. scant in width when dry.

24″ by 6″–4/2″ dimensions:

65. Packed 14/14 courses to the bundle, net count 84 pieces to the bundle, 4 bundles to the roofing square, based on a 7½-in. exposure; 3 bundles to the side wall square, based on a 10-in. exposure.

18″ by 5″–5/2¼″ dimensions:

66. Packed 16/16 courses to the bundle, with 8 additional cross shingles; net count 136 pieces to the bundle, 4 bundles to the square, based on 5½-in. exposure.

18″ by 6″–5/2¼″ dimensions:

67. Packed 17/18 courses to the bundle with 8 additional cross shingles; net count 113 pieces to the bundle, 4 bundles to the square, based on 5½-in. exposure.

16″ by 5″–5/2″ dimensions:

68. Packed 18/18 courses to the bundle, with 8 additional cross shingles; net count 152 pieces to the bundle, 4 bundles to the square, based on a 5-in. exposure.

16″ by 6″–5/2″ dimensions:

69. Packed 19/20 courses to the bundle, with 8 additional cross shingles; net count 125 pieces to the bundle, 4 bundles to the square, based on a 5-in. exposure.

No. 2 Grade

24″ by 6″–4/2″ dimensions:

70. None.

18″ by 5″–5/2¼″ dimensions:

71. None.

18″ by 6″–5/2¼″ dimensions:

72. None.

16″ by 5″–5/2″ dimensions:

16″ by 6″–5/2″ dimensions:

73. These shingles may be mixed grain, strictly clear, with not more than ½-in. sap on any portion exposed to the weather measured from the butt on one edge only.

74. No shingles shall be more than one-fourth inch scant in width when dry.

75. Pack and count the same as for 16-in. No. 1 dimension grades.

SHIPMENT

76. Shingles shall be packed by the "square".

A "square" of shingles shall cover an area of 10 ft. by 10 ft. or 100 square ft., when laid at the prescribed weather exposure.

77. Dimension shingles if not packed by the "square" shall be sold full net count.

78. The openings shall not exceed an average of 1½-in. to the bundle course in random-width shingles.

79. Shingles of all grades must be packed in straight courses in regulation frames 20 in. in width with band sticks not less than 19½ in. long. In random-width shingles there shall be an average of not less than 18½ running inches of shingles per course.

80. Each bundle shall be branded with the full name and number of the grade.

81. A shipment is off grade when the total running inches of defective shingles constitute more than 4 per cent of the shipment.

Pages 552 to 557

CLASSIFICATION OF THE USES OF LUMBER AND TIMBER UNDER AMERICAN RAILWAY ENGINEERING ASSOCIATION SPECIFICATIONS

The grades of lumber and timber hereinafter recommended for various uses in various types of railway structures are those which should ordinarily be employed. In some cases alternate grades are given to accommodate the various species; in some instances alternate items are given for the reason that for a certain member in a certain building 1 in. boards may be adequate while for the same part in another building of otherwise the same character 2 in. dimension may be required.

For work of the highest character a grade higher than those recommended below can be used, and for temporary work, a grade lower.

In yard material the standard grades of Select lumber (i.e. A, B, or B and Better, C, and D) of one producing region or one species compare closely with those of other regions or other species. This is also true of No. 1, No. 2, and No. 3 Dimension.

In boards, however, and material manufactured therefrom such as siding, shiplap, D&M, etc., grades of the same numeral designation are not of corresponding quality in the various softwood species. In some woods boards are assorted into three grades; in other woods they are assorted into four; and in still others into five standard grades, the latter in accordance with American Lumber Standards. The better of these grades in those woods having five grades is higher in quality than in the corresponding grades in those woods having but three or four board grades. In other words, No. 3 Boards in a three-grade division wood, for example, are much lower in quality than No. 3 Boards in a five-grade wood.

This difference in quality of board grades of otherwise the same designation in the different woods is recognized in all lumber industry recommendations relating to boards for different uses. Typical woods having five board grades are the soft and white pines, white fir, Inland Empire Douglas fir, larch and Engelmann spruce. Where a lower alternate board grade is cited in the following recommendations the lower grade applies to those woods.

Structural stress-grades of the same designation apply equally to all species capable of qualifying for the stress-grade in question. The grades recommended for structural, load-bearing purposes are designated in terms of their safe stresses as set forth in the American Railway Engineering Association Structural Timber Specifications given on preceding pages. When it is desired to use woods for which no stress-grades are provided by those specifications, grades of desired strength, and so designated, may be prepared on the basis of the information given in U.S. Department of Agriculture Miscellaneous Publication 185.

1. Bridge and Construction Timber

A. COMBINATION AND HOWE TRUSS SPANS

1. Compression members	1200#c Structural Posts and Timbers
2. Tension members	1600#f or 1400#f Structural Joist and Plank
3. Diagonals subject to reversal of stress	1200#c Structural Posts and Timbers
4. Floor Beams 5. Stringers	1800#f or 1600#f Structural Beams and Stringers
6. Ties	1200#c Structural Posts and Timbers
7. Guard Timbers	1100#c Structural Posts and Timbers
8. Railing	No. 1 Dimension or Timbers
9. Stiffeners	No. 1 Dimension
10. Splices	No. 1 Dimension
11. Nailing Strips	No. 1 Dimension
12. Grillage	1100#c Structural Posts and Timbers
13. Deck Plank	No. 1 Dimension
14. Bridging	No. 2 or No. 3 Boards

1. **Bridge and Construction Timber** (Continued)

B. PILE AND FRAME TRESTLES

1. Sills and Mud Sills	1200#c Structural Posts and Timbers
2. Posts	1200#c Structural Posts and Timbers
3. Caps	1200#c Structural Posts and Timbers
4. Sash Bracing	1200#f or 1100#f Structural Joist and Plank
5. Cross Bracing	1200#f or 1100#f Structural Joist and Plank
6. Longitudinal Bracing	1200#f or 1100#f Structural Joist and Plank
7. Girts	1100#c Structural Posts and Timbers
8. End Planks	1200#f or 1100#f Structural Joist and Plank
9. Stringers	1800#f or 1600#f Structural Beams and Stringers
10. Ties	1200#c Structural Posts and Timbers
11. Guard Timbers	1100#c Structural Posts and Timbers
12. Planking for Ballasted Decking	1600#f or 1400#f Structural Joist and Plank
13. Railing	No. 1 Dimension or Timbers

C. FALSEWORK

1. Sills and Mud Sills	1100#c Structural Posts and Timbers, or No. 1 Timbers
2. Posts	1100#c Structural Posts and Timbers, or No. 1 Timbers
3. Caps	1100#c Structural Posts and Timbers, or No. 1 Timbers
4. Stringers	1600#f or 1400#f Structural Beams and Stringers
5. Truss Timbers	See K 1—Truss Members
6. Centering	No. 1 Dimension
7. Lagging	No. 1 Dimension
8. Bracing	1200#f or 1100#f Structural Joist and Plank
9. Wedges	No. 1 Dimension
10. Scaffolding	No. 1 Dimension

D. CONCRETE FORMS

1. Shoring	No. 1 or No. 2 Dimension
2. D&M Planks	No. 2 or No. 3 Dimension
3. Bracing	No. 2 or No. 3 Boards or Dimension
4. Boarding	No. 2 or No. 3 Boards

E. TANKS AND SUPPORTS

1. Sills	1200#c or 1100#c Structural Posts and Timbers
2. Posts	1200#c or 1100#c Structural Posts and Timbers
3. Caps	1200#c or 1100#c Structural Posts and Timbers
4. Bracing	1200#f or 1100#f Structural Joist and Plank, or No. 1 Dimension
5. Joists	1600#f or 1400#f Structural Joist and Plank, or No. 1 Dimension
6. D&M Flooring	No. 1 Dimension
7. Staves	Tank Stock
8. Rafters	No. 1 Dimension
9. Roof Boards	No. 1 or No. 2 Shiplap or D&M
10. Ladders, etc.	Ladder Stock ASA Standard
11. Frost-box Material	No. 1 or No. 2 Shiplap or D&M, and No. 1 Dimension

F. PIERS AND WHARVES

1. Sheet Piling	1100#c Structural Posts and Timbers, or No. 1 Dimension
2. Cribbing	1100#c Structural Posts and Timbers
3. Caps	1200#c Structural Posts and Timbers
4. Stringers	1800#c or 1600#c Structural Beams and Stringers
5. Bracing	1200#f or 1100#f Structural Joist and Plank

1. Bridge and Construction Timber (Continued)

6. Guard Timbers	1100#c Structural Posts and Timbers
7. Ties	1200#c Structural Posts and Timbers
8. Decking	1600#f or 1400# Structural Joist and Plank
9. Mooring Posts	1200#c Structural Posts and Timbers
10. Fenders and Wales	1100#c Structural Posts and Timbers
11. Warehouse	See Frame Buildings

G. Coaling Stations and Ore Stations

1. Sills and Mud Sills	1100#c Structural Posts and Timbers
2. Posts	1200#c Structural Posts and Timbers
3. Caps	1200#c Structural Posts and Timbers
4. Bracing	1200#f or 1100#f Structural Joist and Plank
5. Stringers	1800#f or 1600#f Structural Beams and Stringers
6. Joists	1600#f or 1400#f Structural Joist and Plank
7. Bin Lining	No. 1 Dimension
8. Rafters	No. 1 Dimension
9. Flooring	No. 1 Boards, or No. 1 Dimension
10. Chutes	No. 1 Boards, or No. 1 Dimension
11. Decking	1200#f or 1100#f Structural Joist and Plank, or No. 1 Dimension
12. Pockets and Bins	No. 1 Dimension
13. Roofing	No. 2 or No. 3 Shiplap or D&M, or No. 1 Dimension
14. Truss Timbers	See K1—Truss Members

H. Tunnels

1. Posts	1200#c Structural Posts and Timbers
2. Sills	1200#c Structural Posts and Timbers
3. Caps	1200#c Structural Posts and Timbers
4. Segments	1200#c Structural Posts and Timbers
5. Lagging	No. 1 Dimension
6. Struts	No. 1 Dimension

J. Caisson

	1200#c Structural Posts and Timbers

K. Truss Members

(For Buildings, Bridges, Heavy Falsework, Coaling & Ore Stations, etc.)

1. Compression and Tension Members 4 in. and Thinner	1600#f or 1400#f Structural Joist and Plank, or No. 1 Dimension
2. Compression Members 6 in. × 6 in. and Larger	1200#c or 1100#c Structural Posts and Timbers, or No. 1 Timbers
3. Tension Members 5 in. and Thicker	1600#f or 1400#f Structural Beams and Stringers, or No. 1 Timbers
4. Purlins 4 in. and Thinner	1600#f or 1400#f Structural Joist and Plank, or No. 1 Dimension
5 in. and Thicker	1600#f or 1400#f Structural Beams and Stringers, or No. 1 Timbers

2. (a) Buildings—Light Framed Construction

A. Station Buildings, Passenger and Freight
B. Platform Shelters
C. Section Houses
D. Small Ice Houses
E. Small Machine Shops
F. Miscellaneous Small Buildings

2. (a) Buildings—Light Framed Construction (Continued)

ROUGH CARPENTRY

1.	Foundation Timbers (Sleepers)	1100#c Structural Posts and Timbers, or No. 1 Timbers
2.	Posts and Columns	1100#c Structural Posts and Timbers, or No. 1 Timbers
3.	Sills	1200#f Structural Joist and Plank, or No. 1 Dimension
4.	Beams, Stringers, Girders, Purlins	
	(a) 4 in. and Thinner	1400#f or 1200#f Structural Joist and Plank
	(b) 5 in. and Thicker	1400#f or 1200#f Structural Beams and Stringers
5.	Joists and Headers	No. 1 Dimension
6.	Bridging	No. 2 or No. 3 Boards
7.	Subflooring	No. 2 or No. 3 Shiplap or D&M
8.	Sleepers or Screeds	No. 2 or No. 3 Dimension
9.	Studs, Plates, Caps, Bucks	No. 2 Dimension
10.	Wall Sheathing	No. 2 or No. 3 Shiplap or D&M
11.	Rafters	No. 1 Dimension
12.	Ribbon Boards, Collar Beams, Ridge Boards, Bracing	No. 1 or No. 2 Boards
13.	Roofing, Pitched	No. 2 or No. 3 Shiplap or D&M
14.	Roofing, Flat	No. 1 or No. 2 Shiplap or D&M, or Dimension
15.	Shingles, Roof	No. 1 Grade
16.	Furring and Grounds	No. 2 or No. 3 Boards
17.	Lath, Wall and Ceiling	No. 1 Lath
18.	Stair Stringers	No. 1 Dimension
19.	Cellar and Attic Stair Treads and Risers	No. 1 or No. 2 Boards, or No. 1 Dimension

EXTERIOR FINISHED CARPENTRY AND MILLWORK

20.	Siding	B and Better or No. 1 Siding
21.	Shingles, Sidewall	No. 2 Grade
22.	Door and Window Frames	C Finish, or No. 1 Frame
23.	Outside Finish Lumber	C or D Finish, or No. 1 Boards
24.	Outside Mouldings	Standard Grade Mouldings
25.	Window Sash	Standard Sash
26.	Doors	No. 1 or No. 2 Doors
27.	Porch Flooring	B and Better or C Flooring, EG or FG
28.	Porch Ceiling	B and Better or C Ceiling
29.	Porch Stair Stringers	No. 1 Dimension
30.	Porch Stair Treads and Risers	B and Better or C Finish or Stepping
31.	Porch Columns	B and Better or C Finish Grade
32.	Porch Railings	Standard Grade Mouldings

INTERIOR FINISHED CARPENTRY AND MILLWORK

33.	Flooring, Softwood, Uncovered	B and Better or C Flooring, EG or FG
34.	Flooring, Softwood, Covered	C or No. 1 or No. 2 Flooring
35.	Flooring, Softwood, Workroom	C or No. 1 Flooring, or No. 1 Dimension, or End-Grain Block Flooring
36.	Flooring, Hardwood, Uncovered	Select, Quarter or Plain Sawed, or No. 1 Plain Sawed Oak Flooring; First or Second Grade Maple Flooring
37.	Flooring, Hardwood, Workroom	No. 1 or No. 2 Oak Flooring; Third Grade Maple Flooring

2. (a) Buildings—Light Framed Construction (Continued)

	For Natural Finishes	*For Paint Finishes*
38. Ceiling	B and Better Ceiling	C, D or No. 1 Ceiling
39. Partition	B and Better Partition	C, D or No. 1 Partition
40. Inside Finish Lumber	B and Better Finish	C or D Finish, or No. 1 Boards
41. Mouldings	Standard Grade Mouldings	Standard Grade Mouldings
42. Stair Treads and Risers	B and Better Finish	C or D Finish
43. Shelving	B and Better or C Finish	D Finish, or No. 1 Boards

2. (b) Buildings—Heavy Framed Construction

A. Engine Houses
B. Large Machine Shops
C. Warehouses
D. Large Ice Houses
E. Large Station Buildings

ROUGH CARPENTRY

1. Foundation Timbers (Sleepers)	1400# or 1200#f Structural Posts and Timbers
2. Posts and Columns	1400# or 1200#f Structural Posts and Timbers
3. Sills	1400#f or 1200#f Structural Joist and Plank
4. Beams, Stringers, Girders, Purlins	
(a) 4 in. and Thinner	1600#f or 1400#f Structural Joist and Plank
(b) 5 in. and Thicker	1600#f or 1400#f Structural Beams and Stringers
5. Joists and Headers	1600#f or 1400#f Structural Joist and Plank
6. Bridging	No. 1 or No. 2 Boards or Dimension
7. Subflooring	No. 2 or No. 3 Boards, or No. 2 Dimension
8. Sleepers or Screeds	
9. Flooring, Plank or Laminated	No. 1 or No. 2 Dimension
10. Studs, Plates, Caps, Bucks	No. 1 or No. 2 Dimension
11. Wall Sheathing	No. 2 or No. 3 Shiplap or D&M
12. Partitions, Plank or Laminated	No. 1 or No. 2 Dimension
13. Rafters	No. 1 Dimension
14. Ribbon Boards, Collar Beams, Ridge Boards, Bracing	No. 1 or No. 2 Boards or Dimension
15. Roofing, Pitched	No. 2 or No. 3 Shiplap or D&M
16. Roofing, Flat	No. 1 or No. 2 Shiplap or D&M or Dimension
17. Shingles, Roof	No. 1 or No. 2 Grade
18. Furring and Grounds	No. 2 or No. 3 Boards
19. Lath, Wall and Ceiling	No. 1 or No. 2 Lath
20. Stair Stringers	1400#f or 1200#f Structural Joist and Plank, or No. 1 Dimension
21. Cellar and Attic Stair Treads and Risers	No. 1 or No. 2 Boards, No. 1 Dimension
22. Shelving, Heavy	No. 1 or No. 2 Dimension
23. Roof Trusses	See 1 K—Truss Members

EXTERIOR FINISHED CARPENTRY AND MILLWORK

For required items, see *2 (a) Light Framed Construction*

INTERIOR FINISHED CARPENTRY AND MILLWORK

For required items, see *2 (a) Light Framed Construction*

3. Miscellaneous Roadway Material

A. CROSSING PLANK	No. 1 Dimension
B. PLATFORMS	
1. Posts	No. 1 Dimension or Timbers
2. Caps	No. 1 Dimension or Timbers
3. Sills	No. 1 Dimension or Timbers
4. Stringers	1600#f or 1400#f Structural Beams and Stringers
5. Joists	1600#f or 1400#f Structural Joist and Plank
6. Bridging	No. 3 Boards
7. Planking	No. 1 Dimension
8. Railing	No. 1 Dimension
9. Steps	No. 1 Boards
10. Skids	No. 1 Dimension
C. STOCK GUARDS	
1. Posts	No. 1 Dimension or Timbers
2. Ties	1200#f Structural Posts and Timbers
3. Wing Fences and Aprons	No. 1 or No. 2 Boards
4. Slats	No. 1 or No. 2 Boards
5. Fillers	No. 2 or No. 3 Boards
D. SIGNS AND POSTS	
1. Posts	No. 1 Dimension or Timbers
2. Bracing	No. 2 Dimension
3. Sign Boards	C or D Finish or No. 1 Boards
4. Moulding	Standard Grade Mouldings
E. FENCING, INCLUDING SNOW FENCE	
1. Posts	No. 1 Dimension or Timbers
2. Bracing	No. 2 or No. 3 Boards
3. Stringers	No. 1 Dimension
4. Fencing	No. 2 or No. 3 Boards
5. Gate Materials	No. 1 Boards or Dimension
6. Stakes	No. 2 or No. 3 Boards or Dimension
F. CULVERTS AND DRAINS	
1. Sills	1100#c Structural Posts and Timbers
2. Bracing	No. 2 or No. 3 Boards
3. Timbers	1200#c Structural Posts and Timbers
4. Planking	No. 2 Dimension
5. Grillage	1100#c Structural Posts and Timbers or 1100#f Structural Joist and Plank
G. STOCK PENS	
1. Posts	No. 1 Dimension or Timbers
2. Sills	No. 1 Dimension or Timbers
3. Fencing	No. 1 Dimension
4. Studding	No. 1 or No. 2 Dimension
5. Sheathing	No. 2 or No. 3 Shiplap or D&M
6. Rafters	No. 1 Dimension
7. Roofing	No. 2 or No. 3 Shiplap or D&M
8. Shingle, Roof	No. 2 Grade
9. Outside Finish Lumber	C or D Finish, or No. 1 Boards
H. POLES	1200#c Structural Posts and Timbers
I. CONDUITS	No. 1 Dimension
J. BUMPING BLOCKS	1200#c Structural Posts and Timbers

Pages 558 to 560

SPECIFICATIONS FOR CONSTRUCTION OAK

and

SPECIFICATIONS FOR STRUCTURAL OAK TIMBERS

Withdraw both.

Appendix B

(2) SIMPLIFICATION OF GRADING RULES AND CLASSIFICATION OF TIMBER FOR RAILWAY USES

W. E. Hawley, Chairman, Sub-Committee; H. M. Church, G. M. Cornell, C. J. Hogue, C. S. Johnson, J. A. Newlin, Arthur Ridgway, A. T. Upson.

The following report and recommendation are the result of two years' study by this Committee, in collaboration with others, in attempting to prepare specifications for wood for structural use in an improved and more convenient form than that given in the 1929 Manual.

There was not available, prior to the publishing of this Manual, the material on which the Committee has written these new specifications. Neither was the lumber producing industry prepared to manufacture and offer material as outlined in the new specifications.

Recent research, study and publication by the U.S. Forest Products Laboratory, with cooperative study by the technical staff of the lumber industry, give hope that these specifications may be widely adopted in the engineering use of wood.

A preliminary report was presented for information at the 1935 Convention and published in Bulletin 374. After intensive study, the Committee made a change in the editorial form of the specifications without altering the general objective in that report. A major editorial change was made to cast the specification in the recommended AREA form. Attention was given to shortening the report as far as possible and the Committee now recommends that the following foreword, specifications, tables and notes on stresses be adopted for publication in the Manual, withdrawing all material now in this section of the Manual in conflict therewith, i. e., pages 505 to 551 and pages 558–560 to end of material on structural oak.

GRADING STRUCTURAL TIMBERS ON THE BASIS OF UNIT WORKING STRESSES—1936

Foreword

1. The following specifications for stress-grades of structural timber conform to the principles of strength-grading as presented in U.S. Department of Agriculture Miscellaneous Publication No. 185, "Guide to the Grading of Structural Timbers and the Determination of Working Stresses", and the stress-grades are in conformity with tests of the Forest Products Laboratory.

2. These specifications represent complete grading rules, capable of use in both engineering design and timber purchase, and incorporate all factors affecting the strength and utility of structural timbers and the method of grading them.

3. Existing commercial grading rules of the regional lumber manufacturers' associations are in conformity generally with the structural grading hereinafter presented, and provide grades of equal or higher working stresses. The following specifications may, therefore, be used for mill orders, or for selection or appraisal of stock on hand in either manufacturers', distributors' or users' storage yards.

4. The designations 1800#f, 1200#c, etc., by which the various stress-grades are identified in these specifications represent safe unit working stresses, applicable to material when used in locations continuously dry or covered: (a) For extreme fiber in bending (f = fiber stress) in the case of joist, plank, beams and stringers, or for longitudinal tension, for which the same stresses as in bending may be used, with grading modified as provided below; and (b) for compression parallel to grain (c = compression stress) for short columns in the case of posts and timbers. These stresses may be used without allowance for impact up to impact of 100 per cent of loads figured. Grade limitations applicable to the center portion of pieces in bending should be applied throughout the entire length of pieces subject to longitudinal tension. The stresses for joist and plank assumed strength increased by seasoning, and were increased accordingly; hence the stresses in extreme fiber should be reduced as provided below when the joist and plank are used where they will not be continuously dry. For timber continuously

submerged, except joist and plank, the stresses for use continuously dry or covered apply except in compression perpendicular to grain, which should not exceed 70 per cent of those stresses since they have been increased for surface drying and consequent increase in hardness and bearing value. For joist and plank continuously submerged, stresses determined from the basic stresses without increase in strength from seasoning, should be used, except in compression perpendicular to grain, which should be taken at 70 per cent of those stresses.

5. The amount by which the stresses for all structural grades and items should be reduced, or the size of the timbers increased, to adapt them to exposed conditions of use, is dependent upon the extent to which the exposure favors decay, required life of the structure or part, frequency and thoroughness of inspection, original cost and cost of replacements, proportion of sapwood and durability of heartwood of the species if untreated, and character and efficiency of the treatment if treated. This is left to the judgment of the engineer. The following percentages of the stress-grade values continuously dry or covered (100 per cent), recommended by the Forest Products Laboratory, may be used as a guide:

Kind of Stress for Treated or Untreated Material	*Occasionally Wet but Quickly Dried Per Cent*
Extreme fiber in bending	87½
Compression perpendicular to grain	70
Compression parallel to grain	92
Horizontal shear	100
Modulus of elasticity	100

When joist and plank are used in exposures "Occasionally wet but quickly dried", the above percentages apply to the original values not increased for seasoning.

6. In locations of more extreme exposure than "Occasionally wet but quickly dried" and where serious depreciation is more apt to occur, a further reduction in the working stresses for extreme fiber and compression may be made, in the judgment of the engineer.

7. No piece of exceptionally light weight should be accepted for structural timber use.

8. For all timber to be given preservative treatment, there should be no heartwood requirement and the amount of sapwood should not be limited.

9. Where wane is not wanted, the order should state "Square Edge".

10. An inquiry or purchase order for structural timber based on these specifications shall clearly stipulate:

(a) Quantity in board feet or number of pieces.
(b) Stress-grade (using complete designation).
(c) Kind of wood.
(d) Item or items.
(e) Thickness, width and length.
(f) Whether rough or surfaced and extent of surfacing.
(g) Whether square edge is required, otherwise the permissible wane of the grade will be considered acceptable.
(h) Heartwood requirement (in percentage of each face).
(i) Whether pithless (side cut) pieces are required, otherwise boxed pith will be considered acceptable.
(j) "In accordance with AREA current specifications", adding any necessary reference to the commercial grading rules of the regional lumber manufacturers association concerned, where the commercial grade supplies material of equal or greater stress value than the AREA stress-grade under consideration.

Example 1: 20,000 bd. ft. 1400 lb. f. Southern Cypress Structural Joist (or Plank), 3 in. × 12 in. × 20 ft., S4S, 85 per cent heartwood, in accordance with AREA current specifications.

Example 2: 140 pieces 1600 lb. f. close-grained Douglas Fir Structural Beams (or Stringers), 8 in. × 16 in. × 24 ft., S1S1E, Square Edge, pithless (side cut), in accordance with AREA current specifications.

Example 3: 48 pieces 1300 lb. f. Dense Longleaf Southern Pine Structural Posts 12 in. × 12 in. × 30 ft., S4S, in accordance with AREA current specifications.

Example 4: 30 pieces 1400 lb. f. Oak Beams 14 in. × 14 in. × 14 ft., rough, in accordance with AREA current specifications.

SPECIFICATIONS FOR STRUCTURAL TIMBERS

MATERIAL

Kinds of Wood

1. The following kinds of wood cut for use as structural timbers, and graded on basis of working stresses as shown in the following rules and tables, will be accepted when specifically mentioned in the order:

White Ash
Beech
Birch
Port Orford Cedar
Western Red Cedar
Chestnut
Southern Cypress
Douglas Fir
Rock Elm
Soft Elm
Black Gum
Red Gum
Eastern Hemlock
Hard Maple
White Oak) except so-called
Red Oak) swamp or water oaks
Southern Pine
Redwood
Tupelo

PHYSICAL REQUIREMENTS

General Quality

2. Except as hereinafter provided, all structural timber shall be free from defects which may impair strength or durability, such as decay, wane, cross grain, holes, knots, shakes, checks or split, any of which is greater in extent or size than provided in tables following.

Decay

3. Only pieces of sound wood, free from any form of decay will be accepted, except in cypress, where peck is permitted to the same size as holes are, and in chestnut, where bark disease removable in standard surfacing (Sec. 41) is permitted in rough pieces. Blue stain is not decay and is permissible in any wood.

Wane

4. Where wane is permitted, the bark shall be entirely removed. Wane is measured on the face of a piece and at point of most wane.

Cross Grain

5. Within the middle half of length of piece, the slope of grain shall not be steeper than permitted in following tables.

Slope of grain shall be measured over a distance sufficiently great to determine the general slope, disregarding slight local deviations.

Heartwood

6. Timbers for use without preservative treatment shall have at the point of most sapwood not less heartwood than the specified percentage of the nominal width on each face.

Close Grain and Density

7. Close-grained Douglas fir and Redwood shall average not less than six nor more than twenty annual rings per inch in Douglas fir and not less than ten nor more than thirty-five annual rings per inch in Redwood.

8. Dense Douglas fir shall average not less than six annual rings per inch and, in addition, one third or more summerwood.

9. Dense Longleaf and Shortleaf Southern Pine shall average not less than six annual rings per inch and, in addition, one-third or more summerwood.

10. Material excluded by the rules for close-grained or dense wood shall be accepted: as close-grained in Douglas fir if averaging 5 or more than 20 rings and one-third or more summerwood; as dense in Douglas fir and pine if averaging one-half or more summerwood.

11. Close-grain and density shall be determined on either one end or the other of each piece, measured over one inch or three inches along a radial line from the pith at right angles to the rings of annual growth and located as hereinafter described.

12. The radial line chosen to determine close-grained or dense wood shall be representative of the average growth of the cross-section. In case of disagreement, two radial lines shall be chosen, and the number of rings per inch and percentage of summerwood shall be the average of these lines.

13. The contrast in color between summerwood (the darker, harder portion of the annual ring) and springwood shall be distinct, except in pieces having considerably more than the minimum summerwood requirement.

14. In pith (boxed-pith) pieces of close-grained Redwood and Douglas fir and dense Douglas fir the line shall extend from the pith to the corner farthest from the pith, except when the line is not representative. Then it shall be shifted sufficiently to present a fair average, but the distance from the pith to the beginning of the 3-in. portion of the line over which measurement shall be made shall not be changed. When the least dimension is 6 in. or less, the 3-in. portion of the line shall begin at a distance of 1 in. from the pith. When the least dimension is more than 6 in., the 3-in. portion of the line shall begin at a distance from the pith equal to ¼ the least dimension of the piece.

15. In pithless (side-cut) pieces the center of the 3-inch portion of the line shall be at the center of the end of the piece.

16. If a 3-in. portion of the line cannot be obtained, the measurement shall be made over as much of a 3-in. portion as is available.

17. In dense Southern Pine pith (boxed-pith) pieces the measurement shall be made over the third, fourth and fifth inches from the pith, except when a 5-inch radial line is not available. Then the inspection shall apply to the second inch from the pith in material less than 8 inches wide or 16 square inches in cross-section, and to the 3 inches farthest from the pith in larger pieces.

18. In pithless pieces the inspection shall apply to 3 inches beginning at the surface nearest the pith in pieces over 3 inches thick and the second inch in thinner pieces.

Holes

19. Holes are limited and measured in the same way as provided for knots.

Knots

General

20. In a timber, graded for use in bending, wide faces shall be taken as vertical faces, and narrow faces as horizontal faces, unless otherwise noted.

21. When the faces of timber are of equal width, Post and Timber grades shall be used unless otherwise noted. When such timber is graded for use in bending, the better pair of opposite faces shall be taken as the horizontal faces and shall be so marked.

Cluster Knots and Knots in Groups

22. Cluster knots and knots in groups shall not be permitted in structural timbers.

Size

23. Knots are permitted to the maximum size shown in following tables and as provided below.

Increase in Size

24. Except in posts and timbers, knots on narrow faces and at edges of wide faces may increase proportionately from size permitted in middle third of length to twice that size at ends of piece, but in beams and stringers no knot shall exceed the size permissible along center line of face. On wide faces knots may increase proportionately from the size permitted at edge to size permitted along center line.

Sum of Sizes

25. All knots within middle half of length on any face shall not exceed the size of largest knot permitted on that face, four and one-half times in joists and planks, and four times in beams and stringers; while in posts and timbers all knots in any 6 inches of length shall not exceed twice the size of largest permissible knot, and two knots of maximum permissible size are not allowed in any 6 inches of length on any face.

Corner Knots

26. Knots crossing corners of pithless (side cut) pieces which do not extend beyond the area of permissible wane are not considered.

Measuring Knots in Joists and Planks

27. In joists and planks the only knots measured on narrow face, except knots that cross the corners of pithless (side cut) pieces, are those which do not show on wide faces, and their size is distance between lines parallel to edges of piece.

28. On wide faces size of knot is its average diameter, except knots which cross the corners of pithless (side cut) pieces and contain the intersections of adjacent faces, which shall be measured only on the end appearing on the face containing the shorter portion or knots which extend entirely across a face, which shall be measured at both ends, both knots between lines parallel to edges of piece.

Measuring Knots in Beams and Stringers

29. In beams and stringers the size of knot on narrow face is the distance between lines enclosing knot and parallel to edges of piece, except knots extending into adjacent fourth of wide face when smallest diameter is size; while the size of knot on wide face is its smallest diameter, but at edges size is limited as on narrow face.

Measuring of Knots in Posts and Timbers

30. In posts and timbers the size of knot on any face is its average diameter, except knots which cross the corners of pithless (side cut) pieces and contain the intersections of adjacent faces, which shall be measured only on the end appearing on the face containing the shorter portion or knots which extend entirely across a face, which shall be measured at both ends, both knots between lines parallel to edges of piece.

Shakes, Checks and Splits

31. Shakes, Checks and Splits are permitted to maximum size shown in following tables, with inspection made when timber is in green condition and as provided below.

32. Sum of sizes of shakes, checks and/or splits shall not exceed permissible size.

33. Shakes, checks and splits are measured at ends of piece and permissible size is determined by width of narrow face.

34. Shakes, checks and splits in joists and planks and beams and stringers are considered only when within middle half of height.

35. Size of shakes is distance between lines parallel to wide faces of piece.

36. Size of shakes in posts and timbers is the greater distance between lines parallel to each pair of opposite faces.

37. Splits and checks shall not extend into piece at middle of width of end a distance greater than size shown in tables.

38. Checks are considered only when within three times the height from the end.

39. Size of checks shall be the sum of seven depth measurements, one on the end and three on each of two sides, divided by three. Each measurement shall be the greatest depth of any check within the above-specified portion of the piece; the measurement on the end made at the middle of the width of the piece and the six measurements on the sides at 1, 2 and 3 times the height of the piece from the end in joist, plank, beams and stringers, and the width of the piece from the end in posts and timbers. Each depth measurement shall be determined by the penetration into the piece of a probe 1/64 inch thick and ¼ inch wide.

DESIGN

Dimensions

40. The standard sizes of structural timbers are as shown in following table.

	Joists and Planks	*Beams and Stringers*	*Posts and Timbers*
Nominal thickness	2″, 3″ and 4″	5″, 6″ and up in multiples of 2″	5″, 6″ and up in multiples of 2″
Nominal width	4″ and up in multiples of 2″	8″ and up in multiples of 2″	5″, 6″ and up in multiples of 2″
Nominal length	6′, 8′, 9′ and 10′ to 40′ in multiples of 2′	6′, 8′, 9′ and 10′ and up in multiples of 2′	6′, 8′, 9′ and 10′ and up in multiples of 2′

Sizes in fractional or odd feet or inches other than those above are special cutting.

Tolerances and Surfacing Allowances

41. The actual dimensions of structural timbers when green shall conform to the following tolerances and surfacing allowances.

	Nominal Thickness	*Minimum* Rough Thickness*	*Surfaced Thickness S1S or S2S*	*Nominal Width*	*Minimum* Rough Width*	*Surfaced Width S1S or S2S*
Joists, planks and other framing members with load applied to either wide face or narrow face.	2"	⅛" off	⅜" off	4"	3/16" off	⅜" off
	3"	3/16" off	do	6"	do	do
	4"	do	do	8" & wdr.	¼" off	½" off
Beams, stringers and other heavy members with load applied to narrow face.	5", 6"	do	½" off		do	do
	8" and thicker	¼" off	do	8" & wdr.		
Posts, timbers and other members to carry longitudinal loads.	5", 6"	3/16" off	do	5", 6"	3/16" off	do
	8" and thicker	¼" off	do	8" and wider	¼" off	do

* Permissible in not to exceed 20 per cent of the pieces in any one shipment.

MANUFACTURE

42. All structural timbers shall be straight, well sawed, sawed square at the ends, have opposite surfaces parallel and be pithless in cedar and redwood.

43. Rough structural timbers shall be sawed full to nominal dimensions, except that occasional slight variation in sawing is permissible. At no part of the length shall any piece, because of such variation in sawing, be under the nominal dimensions more than hereinbefore provided, and no shipment shall contain more than 20 per cent of pieces of minimum dimensions.

44. Structural timbers, ordered rough, if thicker than the count thickness for dry or green stock, may be surfaced to such count thickness and when surfaced shall be considered as rough stock.

45. When so ordered, timbers shall have their ends protected from injurious checks and/or splits, subsequent to their acceptance, with an effective coating or device approved by the buyer.

INSPECTION

Place

46. Timbers will be inspected at suitable and convenient places satisfactory to the railroad, at points of shipment or at destination. Timbers will be inspected at points other than the railway's property when in the judgment of the railway there is sufficient quantity to warrant it; but the shipper shall provide accommodations for the Inspector, at the expense of the railroad, while away from the rail or steamer lines and transport from and to a railway station or steamer landing.

Manner

47. Inspectors will make a reasonably-close examination of the sides and ends of each timber. Each timber will be judged independently, without regard to the decisions on others in the same lot. Timbers too soiled for ready examination will be rejected. Timber will be turned over as inspected, at the expense of the shipper.

SHIPMENT OR DELIVERY

48. Structural timbers shall be separated according to kind of wood, use, item, stress grade and size or as stipulated in the order.

JOIST AND PLANK

STANDARD STRESS-GRADES AND WORKING STRESSES

	Fiber Stress in Bending or Tension				
Grades and Species	Continuously Dry	*Continuously Submerged	Maximum Horizontal Shear	Compression Perpendicular to Grain	Modulus of Elasticity
Softwoods					
1800 lb. f. Dense Douglas Fir (Coast and Inland)	1800	1590	120	380	1,600,000
1800 lb. f. Dense Longleaf and Shortleaf Southern Pine	1800	1590	120	380	1,600,000
1600 lb. f. Close-Grained Douglas Fir (Coast)	1600	1420	100	345	1,600,000
1600 lb. f. Dense Longleaf or Shortleaf Southern Pine	1600	1455	120	380	1,600,000
1600 lb. f. Close-Grained Redwood	1600	1350	80	267	1,200,000
1400 lb. f. Southern Cypress	1400	1220	120	300	1,200,000
1400 lb. f. Dense Longleaf Southern Pine	1400	1320	100	380	1,600,000
1400 lb. f. Close-Grained Redwood	1400	1220	80	267	1,200,000
1200 lb. f. Port Orford Cedar	1200	1045	100	250	1,200,000
1200 lb. f. Douglas Fir (Coast)	1200	1135	100	325	1,600,000
1200 lb. f. Dense Shortleaf Southern Pine	1200	1190	100	380	1,600,000
1200 lb. f. Close-Grained Redwood	1200	1085	70	267	1,200,000
1100 lb. f. Port Orford Cedar	1100	980	80	250	1,200,000
1100 lb. f. Southern Cypress	1100	1020	100	300	1,200,000
1100 lb. f. Eastern Hemlock	1100	980	70	300	1,100,000
1000 lb. f. Western Red Cedar	1000	865	100	200	1,000,000
Hardwoods					
1800 lb. f. White Ash, Red & White Oak	1800	1510	120	500	1,500,000
1800 lb. f. Beech, Birch, Hard Maple	1800	1535	120	500	1,600,000
1800 lb. f. Rock Elm	1800	1535	120	500	1,300,000
1600 lb. f. White Ash, Red and White Oak	1600	1380	120	500	1,500,000
1600 lb. f. Beech, Birch, Hard Maple	1600	1400	120	500	1,600,000
1600 lb. f. Rock Elm	1600	1400	120	500	1,300,000
1400 lb. f. White Ash, Red and White Oak	1400	1245	120	500	1,500,000
1400 lb. f. Beech, Birch, Hard Maple	1400	1265	120	500	1,600,000
1400 lb. f. Rock Elm	1400	1265	120	500	1,300,000
1400 lb. f. Soft Elm	1400	1175	100	250	1,200,000
1400 lb. f. Black & Red Gum, Tupelo	1400	1175	100	300	1,200,000
1200 lb. f. White Ash, Red and White Oak	1200	1110	100	500	1,500,000
1200 lb. f. Beech, Birch, Hard Maple	1200	1135	100	500	1,600,000
1200 lb. f. Chestnut	1200	1010	100	300	1,000,000
1200 lb. f. Rock Elm	1200	1135	100	500	1,300,000
1200 lb. f. Soft Elm	1200	1045	100	250	1,200,000
1200 lb. f. Black and Red Gum, Tupelo	1200	1045	100	300	1,200,000
1000 lb. f. Chestnut	1000	880	100	300	1,000,000
1000 lb. f. Soft Elm	1000	910	100	250	1,200,000
1000 lb. f. Black and Red Gum, Tupelo	1000	910	100	300	1,200,000

*Values under the heading "Continuously Submerged" should be used in application of the percentage of reduction in fiber stress in bending or tension for conditions of exposure which will cause depreciation in strength (paragraph 5, Foreword.)

JOIST AND PLANK (Continued)

(ALL SIZES GIVEN AS INCHES AND FRACTIONS THEREOF.)

(1) 1800 lb. f. DENSE DOUGLAS FIR, COAST OR INLAND; Slope of Grain 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	2/7	3/7	4/7	6/7	1-1/7	1-3/7	1-5/7	2	2-2/7
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	⅝	1	1¼						
At edge of wide face, middle third of length			¾	1	1⅜	1¾	2⅛	2¼	2½
At center line of wide face, middle third of length			1¼	1⅞	2½	3¼	3⅞	4⅛	4½

(2) 1600 lb. f. CLOSE-GRAINED DOUGLAS FIR, COAST; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	⅝	1	1¼						
At edge of wide face, middle third of of length			¾	1	1⅜	1¾	2⅛	2¼	2½
At center line of wide face, middle third of length			1¼	1⅞	2½	3¼	3⅞	4⅛	4½

(3) 1200 lb. f. DOUGLAS FIR, COAST; Slope of grain, 1 in 10

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Wane	½	¾	1	1½	2	2½	3	3½	4
Maximum permissible knots									
On narrow face, middle third of length	⅞	1¼	1¾						
At edge of wide face, middle third of length			1	1½	2	2½	3	3¼	3⅜
At center line of wide face, middle third of length			1¾	2⅝	3½	4¼	5¼	5⅝	6

4) 1800 lb. f. DENSE LONGLEAF AND SHORTLEAF SOUTHERN PINE; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	3/5	9/10	1-1/5	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots									
On narrow face, middle third of length	⅝	1	1¼						
At edge of wide face, middle third of length			¾	1	1⅜	1¾	2⅛	2¼	2½
At center line of wide face, middle third of length			1¼	1⅞	2½	3¼	3⅞	4⅛	4½

(5) 1600 lb. f. DENSE LONGLEAF AND SHORTLEAF SOUTHERN PINE; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	3/5	9/10	1-1/5	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5
Wane	2/5	3/5	4/5	1-1/5	1-3/5	2	2-2/5	2-4/5	3-1/5
Maximum permissible knots,									
On narrow face, middle third of length	¾	1⅛	1½						
At edge of wide face, middle third of length			⅞	1¼	1⅝	2⅛	2½	2¾	2⅞
At center line of wide face, middle third of length			1½	2¼	3	3¾	4½	4⅞	5⅛

(6) 1400 lb. f. DENSE LONGLEAF SOUTHERN PINE; Slope of grain, 1 in 10

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	4/5	1-1/5	1-3/5	2-2/5	3-1/5	4	4-1/5	5-3/5	6-2/5
Wane	½	¾	1	1½	2	2½	3	3½	4
Maximum permissible knots									
On narrow face, middle third of length	⅞	1¼	1¾						
At edge of wide face, middle third of length			1	1½	2	2½	3	3¼	3⅜
At center line of wide face, middle third of length			1¾	2⅝	3½	4¼	5¼	5⅝	6

(7) 1200 lb. f. DENSE SHORTLEAF SOUTHERN PINE; Slope of grain, 1 in 8

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	4/5	1-1/5	1-3/5	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5
Wane	½	¾	1	1½	2	2½	3	3½	4
Maximum permissible knots,									
On narrow face, middle third of length	1	1½	2						
At edge of wide face, middle third of length			1⅛	1¾	2¼	2⅞	3½	3¾	4
At center line of wide face, middle third of length			2	3	3⅞	4⅞	5⅞	6⅜	6⅞

JOIST AND PLANK (Continued)

(ALL SIZES GIVEN AS INCHES AND FRACTIONS THEREOF.)

(8) 1600 lb. f. CLOSE-GRAINED REDWOOD; Slope of grain, 1 in 16

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	2/7	3/7	4/7	6/7	1-1/7	1-3/7	1-5/7	2	2-2/7
Wane	¼	⅜	½	¾	1	1¼	1½	1¾	2
Maximum permissible knots,									
On narrow face, middle third of length	⅜	⅝	⅞						
At edge of wide face, middle third of length			⅜	⅝	⅞	1⅛	1¼	1⅜	1½
At center line of wide face, middle third of length			⅞	1¼	1¾	2⅛	2½	2¾	3

(9) 1400 lb. f. CLOSE-GRAINED REDWOOD; Slope of grain, 1 in 14

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	2/7	3/7	4/7	6/7	1-1/7	1-3/7	1-5/7	2	2-2/7
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	½	⅞	1⅛						
At edge of wide face, middle third of length			⅝	⅞	1¼	1½	1⅞	2	2⅛
At center line of wide face, middle third of length			1⅛	1⅝	2¼	2⅞	3⅜	3⅝	3⅞

(10) 1200 lb. f. CLOSE-GRAINED REDWOOD; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	½	¾	1	1½	2	2½	3	3½	4
Wane	2/5	3/5	4/5	1-1/5	1-3/5	2	2-2/5	2-4/5	3-1/5
Maximum permissible knots,									
On narrow face, middle third of length	¾	1⅛	1½						
At edge of wide face, middle third of length			⅞	1¼	1⅝	2	2⅜	2⅝	2¾
At center line of wide face, middle third of length			1⅜	2⅛	2⅞	3⅝	4⅜	4¾	5

(11) 1400 lb. f. SOUTHERN CYPRESS; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	1/5	3/10	2/5	3/5	4/5	1	1-1/5	1-2/5	1-3/5
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	⅝	⅞	1⅛						
At edge of wide face, middle third of length			⅝	1	1¼	1⅝	1⅞	2	2¼
At center line of wide face, middle third of length			1⅛	1¾	2⅜	2⅞	3½	3¾	4⅛

(12) 1100 lb. f. SOUTHERN CYPRESS; Slope of grain, 1 in 10

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	½	¾	1	1½	2	2½	3	3½	4
Wane	½	¾	1	1½	2	2½	3	3½	4
Maximum permissible knots,									
On narrow face, middle third of length	¾	1¼	1⅝						
At edge of wide face, middle third of length			⅞	1⅜	1⅞	2⅜	2¾	3	3¼
At center line of wide face, middle third of length			1⅝	2½	3¼	4⅛	5	5⅜	5¾

(13) 1200 lb. f. PORT ORFORD CEDAR; Slope of grain, 1 in 14

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	½	⅞	1⅛						
At edge of wide face, middle third of length			⅝	⅞	1¼	1½	1⅞	2	2⅛
At center line of wide face, middle third of length			1⅛	1⅝	2¼	2⅞	3⅜	3⅝	3⅞

(14) 1100 lb. f. PORT ORFORD CEDAR; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	⅔	1	1⅓	2	2⅔	3⅓	4	4⅔	5⅓
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	⅝	1	1⅜						
At edge of wide face, middle third of length			¾	1⅛	1½	1⅞	2¼	2⅜	2½
At center line of wide face, middle third of length			1¼	2	2⅝	3¼	4	4¼	4⅝

JOIST AND PLANK (Continued)

(All Sizes Given as Inches and Fractions Thereof.)

(15) 1100 lb. f. Eastern Hemlock; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	½	¾	1	1½	2	2½	3	3½	4
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	⅝	1	1⅜						
At edge of wide face, middle third of length			¾	1⅛	1½	1⅞	2¼	2⅜	2½
At center line of wide face, middle third of length			1¼	2	2⅝	3¼	4	4¼	4⅝

(16) 1000 lb. f. Western Red Cedar; Slope of grain, 1 in 14

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	1/9	1/6	2/9	⅓	4/9	1-5/9	1-5/9	7/9	8/9
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	½	⅞	1⅛						
At edge of wide face, middle third of length			⅝	⅞	1¼	1½	1¾	2	2⅛
At center line of wide face, middle third of length			1⅛	1⅝	2¼	2¾	3⅜	3⅝	3⅞

(17) 1800 lb. f. White Ash, Red and White Oak, Slope of grain, 1 in 16

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	3/5	9/10	1-1/5	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5
Wane	¼	⅜	½	¾	1	1¼	1½	1¾	2
Maximum permissible knots,									
On narrow face, middle third of length	⅜	⅝	¾						
At edge of wide face, middle third of length			⅜	⅝	¾	1	1¼	1¼	1⅜
At center line of wide face, middle third of length			¾	1⅛	1½	1¾	2¼	2½	2⅝

(18) 1600 lb. f. White Ash, Red and White Oak; Slope of grain, 1 in 14

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	3/5	9/10	1-1/5	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	½	¾	1						
At edge of wide face, middle third of length			½	⅞	1⅛	1⅜	1¾	1⅞	2
At center line of wide face, middle third of length			1	1¾	2	2⅝	3⅛	3⅜	3⅝

(19) 1400 lb. f. White Ash, Red and White Oak; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	½	¾	1	1½	2	2½	3	3½	4
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	⅝	1	1⅜						
At edge of wide face, middle third of length			¾	1⅛	1½	1⅞	2¼	2⅜	2½
At center line of wide face, middle third of length			1¼	2	2⅝	3¼	4	4¼	4⅝

(20) 1200 lb. f. White Ash, Red and White Oak; Slope of grain, 1 in 10

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	4/5	1-1/5	1-3/5	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5
Wane	½	¾	1	1½	2	2½	3	3½	4
Maximum permissible knots,									
On narrow face, middle third of length	¾	1¼	1⅝						
At edge of wide face, middle third of length			⅞	1⅜	1¾	2¼	2¾	3	3⅛
At center line of wide face, middle third of length			1⅝	2⅜	3¼	4	4⅞	5¼	5⅝

(21) 1800 lb. f. Beech, Birch, Hard Maple, Rock Elm; Slope of grain, 1 in 15

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	3/5	9/10	1-1/5	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5
Wane	¼	⅜	½	¾	1	1¼	1½	1¾	2
Maximum permissible knots,									
On narrow face, middle third of length	½	⅝	⅞						
At edge of wide face, middle third of length			½	¾	1	1¼	1½	1⅝	1¾
At center line of wide face, middle third of length			⅞	1⅜	1⅞	2¼	2¾	3	3¼

JOIST AND PLANK (Continued)

(ALL SIZES GIVEN AS INCHES AND FRACTIONS THEREOF.)

(22) 1600 lb. f. BEECH, BIRCH, HARD MAPLE, ROCK ELM; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	3/5	9/10	1-1/5	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	⅝	⅞	1¼						
At edge of wide face, middle third of length			⅝	1	1¼	1⅝	2	2⅛	2¼
At center line of wide face			1¼	1¾	2¼	3	3⅝	3⅞	4¼

(23) 1400 lb. f. BEECH, BIRCH, HARD MAPLE, ROCK ELM: Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	3/5	9/10	1-1/5	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5
Wane	2/5	3/5	4/5	1-1/5	1-3/5	2	2-2/5	2-4/5	3-1/5
Maximum permissible knots,									
On narrow face, middle third of length	¾	1⅛	1⅜						
At edge of wide face, middle third of length			¾	1¼	1⅝	2	2⅜	2⅝	2¾
At center line of wide face			1⅜	2⅛	2⅞	3⅝	4⅜	4¾	5

(24) 1200 lb. f. BEECH, BIRCH, HARD MAPLE, ROCK ELM; Slope of grain, 1 in 10

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	4/5	1-1/5	1-3/5	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5
Wane	½	¾	1	1½	2	2½	3	3½	4
Maximum permissible knots,									
On narrow face, middle third of length	⅞	1¼	1¾						
At edge of wide face, middle third of length			1	1½	2	2½	3	3¼	3⅜
At center line of wide face			1¾	2⅝	3½	4¼	5¼	5⅝	6

(25) 1200 lb. f. CHESTNUT; Slope of grain, 1 in 16

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Wane	¼	⅜	½	¾	1	1¼	1½	1¾	2
Maximum permissible knots,									
On narrow face, middle third of length	⅜	⅝	¾						
At edge of wide face, middle third of length			⅜	⅝	⅞	1	1¼	1⅜	1½
At center line of wide face			¾	1¼	1⅝	2	2⅜	2⅝	2¾

(26) 1000 lb. f. CHESTNUT; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	⅝	⅞	1¼						
At edge of wide face, middle third of length			⅝	1	1¼	1⅝	2	2⅛	2¼
At center line of wide face			1¼	1¾	2⅜	3	3⅝	3⅞	4¼

(27) 1400 lb. f. BLACK GUM, RED GUM, TUPELO, SOFT ELM; Slope of grain, 1 in 16

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	½	¾	1	1½	2	2½	3	3½	4
Wane	¼	⅜	½	¾	1	1¼	1½	1¾	2
Maximum permissible knot,									
On narrow face, middle third of length	⅜	⅝	¾						
At edge of wide face, middle third of length			⅜	⅝	¾	1	1¼	1¼	1⅜
At center line of wide face			¾	1⅛	1⅝	1⅞	2⅜	2½	2⅝

(28) 1200 lb. f. BLACK GUM, RED GUM, TUPELO, SOFT ELM; Slope of grain, 1 in 14

Nominal width of face	2	3	4	6	8	10	13	14	16
Shakes, checks & splits—green	½	¾	1	1½	2	2½	3	3½	4
Wane	⅓	½	⅔	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,									
On narrow face, middle third of length	½	⅞	1⅛						
At edge of wide face, middle third of length			⅝	⅞	1¼	1½	1⅞	2	2⅛
At center line of wide face			1⅜	1⅝	2¼	2⅞	3⅜	3⅝	3⅞

(29) 1000 lb. f. BLACK GUM, RED GUM, TUPELO, SOFT ELM; Slope of grain, 1 in 12

Nominal width of face	2	3	4	6	8	10	12	14	16
Shakes, checks & splits—green	½	¾	1	1½	2	2½	3	3½	4
Wane	2/5	3/5	4/5	1-1/5	1-3/5	2	2-2/5	2-4/5	3-1/5
Maximum permissible knots,									
On narrow face, middle third of length	¾	1⅛	1½						
At edge of wide face, middle third of length			⅞	1¼	1⅝	2⅛	2½	2¾	2⅞
At center line of wide face			1½	2¼	3	3¾	4½	4⅞	5⅛

BEAMS AND STRINGERS

STANDARD STRESS-GRADES AND WORKING STRESSES

Grades and Species	Fiber Stress in Bending or Tension	Maximum Horizontal Shear	Compression Perpendicular to Grain	Modulus of Elasticity
Softwoods				
1800 lb. f. Dense Dougals Fir (Coast & Inland)	1800	120	380	1,600,000
1800 lb. f. Dense Longleaf & Shortleaf Southern Pine	1800	120	380	1,600,000
1600 lb. f. Close-Grained Douglas Fir (Coast)	1600	100	345	1,600,000
1600 lb. f. Dense Longleaf & Shortleaf Southern Pine	1600	120	380	1,600,000
1600 lb. f. Close-Grained Redwood	1600	80	267	1,200,000
1400 lb. f. Southern Cypress	1400	120	300	1,200,000
1400 lb. f. Dense Longleaf Southern Pine	1400	100	380	1,600,000
1400 lb. f. Close-Grained Redwood	1400	80	267	1,200,000
1200 lb. f. Dense Shortleaf Southern Pine	1200	100	380	1,600,000
1200 lb. f. Close-Grained Redwood	1200	70	267	1,200,000
1100 lb. f. Port Orford Cedar	1100	80	250	1,200,000
1100 lb. f. Southern Cypress	1100	100	300	1,200,000
1100 lb. f. Eastern Hemlock	1100	70	300	1,100,000
1000 lb. f. Western Red Cedar	1000	100	200	1,000,000
Hardwoods				
1600 lb. f. White Ash, Red & White Oak	1600	120	500	1,500,000
1600 lb. f. Beech, Birch, Hard Maple	1600	120	500	1,600,000
1600 lb. f. Rock Elm	1600	120	500	1,300,000
1400 lb. f. White Ash, Red & White Oak	1400	120	500	1,500,000
1400 lb. f. Beech, Birch, Hard Maple	1400	120	500	1,600,000
1400 lb. f. Rock Elm	1400	120	500	1,300,000
1200 lb. f. White Ash, Red & White Oak	1200	100	500	1,500,000
1200 lb. f. Beech, Birch, Hard Maple	1200	100	500	1,600,000
1200 lb. f. Rock Elm	1200	100	500	1,300,000
1200 lb. f. Soft Elm	1200	100	250	1,200,000
1200 lb. f. Black Gum, Red Gum, Tupelo	1200	100	300	1,200,000
1000 lb. f. Chestnut	1000	100	300	1,000,000
1000 lb. f. Soft Elm	1000	100	250	1,200,000
1000 lb. f. Black Gum, Red Gum, Tupelo	1000	100	300	1,200,000

BEAMS AND STRINGERS (Continued)

(All Sizes Given as Inches and Fractions Thereof.)

(30) 1800 lb. f. Dense Dougals Fir Coast and Inland; Slope of grain, 1 in 15

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	5/7	6/7	1-1/7	1-3/7	1-5/7	2	2-2/7		
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots,									
On narrow face, middle third of length	1⅛	1⅜	1⅝	1¾	1⅞	2⅛	2¼		
At center line of wide face			1⅞	2¼	2⅝	2⅞	3⅛	3⅜	3½

(31) 1600 lb. f. Close-Grained Douglas Fir, Coast; Slope of grain, 1 in 15

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	5/6	1	1⅓	1⅔	2	2⅓	2⅔		
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible knots,									
On narrow face, middle third of length	1⅛	1⅜	1⅝	1¾	1⅞	2⅛	2¼		
At center line of wide face			1⅞	2¼	2⅝	2⅞	3⅛	3⅜	3½

(32) 1800 lb. f. Dense Longleaf and Shortleaf Southern Pine; Slope of grain, 1 in 15

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1½	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5		
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots,									
On narrow face, middle third of length	1⅛	1⅜	1⅝	1¾	1⅞	2⅛	2¼		
At center line of wide fce			1⅞	2¼	2⅝	2⅞	3⅛	3⅜	3½

(33) 1600 lb. f. Dense Longleaf and Shortleaf Southern Pine; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1½	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5	----------	
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible knots,									
On narrow face, middle third of length	1½	1⅞	2⅛	2⅜	2⅝	2⅞	3		
At center line of wide face			2½	3⅛	3¾	4	4⅜	4⅝	4⅞

(34) 1400 lb. f. Dense Longleaf Southern Pine; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5		
Wane	1¼	1½	2	2½	3	3½	4	4½	5
Maximum permissible knots,									
On narrow face, middle third of length	2	2⅜	2¾	3⅛	3⅜	3⅝	4		
At center line of wide face			3¼	4	4⅞	5¼	5⅝	5⅞	6¼

(35) 1200 lb. f. Dense Shortleaf Southern Pine; Slope of grain, 1 in 8

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5		
Wane	1¼	1½	2	2½	3	3½	4	4½	5
Maximum permissible knots,									
On narrow face, middle third of length	2⅜	2⅞	3⅜	3¾	4⅛	4⅜	4¾		
At center line of wide face			3⅞	4⅞	5¾	6¼	6¾	7⅛	7½

(36) 1600 lb. f. Close-Grained Redwood; Slope of grain, 1 in 20

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	5/7	6/7	8/7	1-3/7	1-5/7	2	2-2/7		
Wane	½	3/5	4/5	1	1-1/5	1-2/5	1-3/5	1-4/5	2
Maximum permissible knots,									
On narrow face, middle third of length	⅜	⅜	½	½	⅝	⅝	¾		
At center line of wide face			½	⅝	¾	⅞	⅞	1	1

(37) 1400 lb. f. Close-Grained Redwood; Slope of grain, 1 in 18

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	5/7	6/7	1-1/7	1-3/7	1-5/7	2	2-2/7		
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots,									
On narrow face, middle third of length	7/8	1⅛	1¼	1⅜	1½	1⅝	1¾	2¾	
At center line of wide face			1½	1¾	2¼	2⅜	2½	2¾	

(38) 1200 lb. f. Close-Grained Redwood; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1¼	1½	2	2½	3	3½	4		
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible knots,									
On narrow face, middle third of length	1½	1¾	2⅛	2⅜	2⅝	2¾	3		
At center line of wide face			2⅜	3	3⅝	3⅞	4¼	4½	4¾

(39) 1400 lb. f. Southern Cypress; Slope of grain, 1 in 16

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	½	3/5	4/5	1	1-1/5	1-2/5	1-3/5		
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots,									
On narrow face, middle third of length	1	1⅛	1⅜	1½	1⅝	1¾	1⅞		
At center line of wide face			1½	1⅞	2¼	2½	2⅝	2⅞	3

BEAMS AND STRINGERS (Continued)

(ALL SIZES GIVEN AS INCHES AND FRACTIONS THEREOF.)

(40) 1100 lb. f. SOUTHERN CYPRESS; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1¼	1½	2	2½	3	3½	4		
Wane	1	1-1/5	1-3/5	2	2-2/5	2-4/5	3-1/5	3-3/5	4
Maximum permissible knots, On narrow face, middle third of length	1¾	2⅛	2½	2¾	3⅛	3⅜	3½		
At center line of wide face			2⅞	3⅝	4⅜	4¾	5	5⅜	5⅝

(41) 1100 lb. f. EASTERN HEMLOCK; Slope of grain, 1 in 15

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1¼	1½	2	2½	3	3½	4		
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible knots, On narrow face, middle third of length	1¼	1½	1¾	2	2⅛	2¼	2½		
At center line of wide face			2	2½	3	3¼	3½	3¾	3⅞

(42) 1100 lb. f. PORT ORFORD CEDAR; Slope of grain, 1 in 15

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1⅔	2	2⅔	3⅓	4	4⅔	5⅓		
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible On narrow face, middle third of length	1¼	1½	1¾	2	2⅛	2¼	2½		
At center line of wide face			2	2½	3	3¼	3½	3¾	3⅞

(43) 1000 lb. f. WESTERN RED CEDAR; Slope of grain, 1 in 18

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	⅝	¾	1	1¼	1½	1¾	2		
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots, On narrow face, middle third of length	¾	1	1⅛	1¼	1⅜	1½	1⅝		
At center line of wide face			1⅜	1⅝	2	2⅛	2¼	2⅜	2½

(44) 1600 lb. f. WHITE ASH, RED AND WHITE OAK, Slope of grain, 1 in 18

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	1½	1-4/5	2-2/5	3	3-3/5	4-1/5	6-2/5
Wane	⅝	¾	1	1¼	1½	1¾	2
Maximum permissible knots, On narrow face, middle third of length	¾	⅞	1	1⅛	1¼	1¼	1⅜
At center line of wide face			1⅛	1⅜	1¾	1⅞	2

(45) 1400 lb. f. WHITE ASH, RED AND WHITE OAK; Slope of grain, 1 in 15

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	1¼	1½	2	2½	3	3½	4
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots, On narrow face, middle third of length	1¼	1½	1¾	2	2⅛	2¼	2½
At center line of wide face			2	2½	3	3¼	3½

(46) 1200 lb. f. WHITE ASH, RED AND WHITE OAK; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5
Wane	1	1-1/5	1-3/5	2	2-2/5	2-4/5	3-1/5
Maximum permissible knots, On narrow face, middle third of length	1¾	2⅛	2⅜	2¾	3	3¼	3½
At center line of wide face			2⅞	3½	4¼	4⅝	4⅞

(47) 1600 lb. f. BEECH, BIRCH, HARD MAPLE, ROCK ELM; Slope of grain, 1 in 16

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	1½	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5
Wane	⅝	¾	1	1⅛	1½	1¾	2
Maximum permissible knots, On narrow face, middle third of length	1	1¼	1⅜	1⅝	1¾	1⅞	2
At center line of wide face			1⅝	2	2⅜	2⅝	2¾

(48) 1400 lb. f. BEECH, BIRCH, HARD MAPLE, ROCK ELM: Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	1½	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots, On narrow face, middle third of length	1½	1¾	2⅛	2⅜	2⅝	2¾	3
At center line of wide face			2⅜	3	3⅝	3⅞	4¼

(49) 1200 lb. f. BEECH, BIRCH, HARD MAPLE, ROCK ELM; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5
Wane	1¼	1½	2	2½	3	3½	4
Maximum permissible knots, On narrow face, middle third of length	2	2⅜	2¾	3⅛	3⅜	3⅝	4
At center line of wide face			3¼	4	4⅞	5¼	5⅝

BEAMS AND STRINGERS (Continued)

(All Sizes Given as Inches and Fractions Thereof.)

(50) 1200 lb. f. Black Gum, Red Gum, Tupelo, Soft Elm; Slope of grain, 1 in 18

Nominal width of face	5	6	8	10	12	14	16
Shake, checks & splits—green	1¼	1½	2	2½	3	3½	4
Wane	⅝	¾	1	1¼	1½	1¾	2
Maximum permissible knots,							
On narrow face, middle third of length	7/8	1⅛	1¼	1⅜	1½	1⅝	1¾
At center line of wide face			1½	1¾	2¼	2⅜	2½

(51) 1000 lb. f. Black Gum, Red Gum, Tupelo Soft Elm; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16
Shake, checks & splits—green	1¼	1½	2	2½	3	3½	4
Wane	5,6	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots,							
On narrow face, middle third of length	1½	1⅞	2⅛	2⅜	2⅝	2⅞	3
At center line of wide face			2½	3⅛	3¾	4	4⅜

(52) 1000 lb. f. Chestnut; Slope of grain, 1 in 16

Nominal width of face	5	6	8	10	12	14	16
Shake, checks & splits—green	5/6	1	1⅓	1⅔	2	1¾	2
Wane	⅝	¾	1	1¼	1½	1¾	2
Maximum permissible knots,							
On narrow face, middle third of length	1	1¼	1½	1⅝	1¾	2	2⅛
At center line of wide face			1¾	2⅛	2½	2¾	3

POSTS AND TIMBERS

STANDARD STRESS-GRADES AND WORKING STRESSES

Grades and Species	Compression Parallel to Grain, Short Columns	Compression Perpendicular to Grain	Modulus of Elasticity
Softwoods			
1300 lb. c. Dense Douglas Fir (Coast and Inland)	1300	380	1,600,000
1300 lb. c. Dense Longleaf and Shortleaf Southern Pine	1300	380	1,600,000
1200 lb. c. Southern Cypress	1200	300	1,200,000
1200 lb. c. Close-Grained Douglas Fir (Coast)	1200	345	1,600,000
1200 lb. c. Dense Longleaf and Shortleaf Southern Pine	1200	380	1,600,000
1200 lb. c. Close-Grained Redwood	1200	267	1,200,000
1100 lb. c. Douglas Fir (Coast)	1100	325	1,600,000
1100 lb. c. Close-Grained Redwood	1100	267	1,200,000
1000 lb. c. Port Orford Cedar	1000	250	1,200,000
1000 lb. c. Southern Cypress	1000	300	1,200,000
1000 lb. c. Dense Longleaf Southern Pine	1000	380	1,600,000
1000 lb. c. Close-Grained Redwood	1000	267	1,200,000
900 lb. c. Port Orford Cedar	900	250	1,200,000
900 lb. c. Dense Shortleaf Southern Pine	900	380	1,600,000
800 lb. c. Western Red Cedar	800	200	1,000,000
Hardwoods			
1300 lb. c. Beech, Birch, Hard Maple	1300	500	1,600,000
1300 lb. c. Rock Elm	1300	500	1,300,000
1200 lb. c. White Ash	1200	500	1,500,000
1200 lb. c. Beech, Birch, Hard Maple	1200	500	1,600,000
1200 lb. c. Rock Elm	1200	500	1,300,000
1100 lb. c. Red and White Oak	1100	500	1,500,000
1000 lb. c. White Ash	1000	500	1,500,000
1000 lb. c. Beech, Birch, Hard Maple	1000	500	1,600,000
1000 lb. c. Rock Elm	1000	500	1,300,000
1000 lb. c. Red and White Oak	1000	500	1,500,000
900 lb. c. Chestnut	900	300	1,000,000
900 lb. c. Soft Elm	900	250	1,200,000
900 lb. c. Black Gum, Red Gum, Tupelo	900	300	1,200,000

POSTS AND TIMBERS (Continued)

(All Sizes Given as Inches and Fractions Thereof.)

(53) 1300 lb. c. Dense Douglas Fir, Coast or Inland; Slope of grain 1 in 12

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5	7-1/5	8
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots,									
At any point on any face	1¼	1½	1⅞	2⅜	2⅞	3⅛	3⅜	3½	3¾

(54) 1200 lb. c. Close-Grained Douglas Fir, Coast; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5	7-1/5	8
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots,									
At any point on any face	1⅛	1⅜	1⅞	2⅜	2¾	2	3¼	3⅜	3⅝

POSTS AND TIMBERS (Continued)

(All Sizes Given as Inches and Fractions Thereof.)

(55) 1100 lb. c. Douglas Fir, Coast; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5	7-1/5	8
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible knots, At any point on any face	1¼	1½	2	2½	3	3¼	3½	3¾	3⅞

(56) 1300 lb. c. Dense Longleaf and Shortleaf Southern Pine; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5	7-1/5	8
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots, At any point on any face	1¼	1½	1⅞	2⅜	2⅞	3⅛	3⅜	3½	3¾

(57) 1200 lb. c. Dense Longleaf and Shortleaf Southern Pine; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5	7-1/5	8
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible knots, At any point on any face	1½	1¾	2⅜	3	3⅝	3⅞	4¼	4½	4¾

(58) 1000 lb. c. Dense Longleaf Southern Pine; Slope of grain, 1 in 8

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2½	3	4	5	6	7	8	9	10
Wane	1¼	1½	2	2½	3	3½	4	4½	5
Maximum permissible knots, At any point on any face	2⅛	2½	3⅜	4⅛	5	5⅜	5¾	6⅛	6⅜

(59) 900 lb. c. Dense Shortleaf Southern Pine; Slope of grain, 1 in 6

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2-7/9	3⅓	4-4/9	5-5/9	6⅔	7-7/9	8-8/9	10	11-1/9
Wane	1¼	1½	2	2½	3	3½	4	4½	5
Maximum permissible knots, At any point on any face	2⅜	2⅞	3¾	4¾	5⅝	6⅛	6½	7	7¼

(60) 1200 lb. c. Southern Cypress; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1⅔	2	2⅔	3⅓	4	4⅔	5⅓	6	6⅔
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots, At any point on any face	⅞	1⅛	1½	1¾	2¼	2⅜	2½	2¾	2¾

(61) 1000 lb. c. Southern Cypress; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2-2/9	2⅔	3-5/9	4-4/9	5⅓	6-2/9	7-1/9	8	8-8/9
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible knots, At any point on any face	1⅝	1⅞	2½	3¼	3¾	4	4⅜	4¾	5

(62) 1200 lb. c. Close-Grained Redwood; Slope of grain, 1 in 14

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1⅔	2	2⅔	3⅓	4	4⅔	5⅓	6	6⅔
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots, At any point on any face	¾	⅞	1¼	1½	1⅞	2	2⅛	2¼	2⅜

(63) 1100 lb. c. Close-Grained Redwood; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1⅞	2¼	3	3¾	4½	5¼	6	6¾	7½
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots, At any point on any face	1⅛	1⅜	1¾	2¼	2⅝	2⅞	3⅛	3¼	3½

(64) 1000 lb. c. Close-Grained Redwood; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2-1/7	2-4/7	3-3/7	4-2/7	5-1/7	6	6-6/7	7-5/7	8-4/7
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible knots, At any point on any face	1½	1¾	2⅜	2⅞	3½	3¾	4⅛	4⅜	4⅝

(65) 1000 lb. c. Port Orford Cedar; Slope of grain, 1 in 14

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1⅔	2	2⅔	3¼	4	4⅔	5⅓	6	6⅔
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots, At any point on any face	⅞	1	1⅜	1⅝	2	2⅛	2¼	2⅜	2½

(66) 900 lb. c. Port Orford Cedar; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5	7-1/5	8
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔	3	3⅓
Maximum permissible knots, At any point on any face	1¼	1½	2	2½	3	3¼	3½	3¾	3⅞

(67) 800 lb. c. Western Red Cedar; Slope of grain, 1 in 14

Nominal width of face	5	6	8	10	12	14	16	18	20
Shakes, checks & splits—green	1½	1-4/5	2-2/5	3	3-3/5	4-1/5	4-4/5	5-2/5	6
Wane	⅝	¾	1	1¼	1½	1¾	2	2¼	2½
Maximum permissible knots, At any point on any face	¾	¾	1⅛	1⅜	1¾	1⅞	2	2⅛	2¼

POSTS AND TIMBERS (Continued)

(ALL SIZES GIVEN AS INCHES AND FRACTIONS THEREOF.)

(68) 1300 lb. c. BEECH, BIRCH, HARD MAPLE, ROCK ELM; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	1⅔	2	2⅔	3⅓	4	4⅔	5⅓
Wane	⅝	¾	1	1¼	1½	1¾	2
Maximum permissible knots, At any point on any face	⅞	1⅛	1½	1⅞	2¼	2⅜	2½

(69) 1200 lb. c. BEECH, BIRCH, HARD MAPLE, ROCK ELM; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	2	2-2/5	3-1/5	4	4-4/5	5-3/5	6-2/5
Wane	5, 6	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knot, At any point on any face	1¼	1½	2	2½	3	3¼	3½

(70) 1000 lb. c. BEECH, BIRCH, HARD MAPLE, ROCK ELM; Slope of grain, 1 in 8

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	2½	3	4	5	6	7	8
Wane	1	1-1/5	1-3/5	2	2-2/5	2-4/5	3-1/5
Maximum permissible knots, At any point on any face	1⅞	2¼	3	3¾	4½	4⅞	5⅛

(71) 1200 lb. c. WHITE ASH; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	1⅔	2	2⅔	3⅓	4	4⅔	5⅓
Wane	⅝	¾	1	1¼	1½	1¾	2
Maximum permissible knots, At any point on any face	⅞	1⅛	1½	1¾	2¼	2⅜	2½

(72) 1000 lb. c. WHITE ASH; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	2-2/9	2⅔	3-5/9	4-4/9	5⅓	6-2/9	7-1/9
Wane	5, 6	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots, At any point on any face	1⅝	1⅞	2½	3⅛	3¾	4	4⅜

(73) 1100 lb. c. RED AND WHITE OAK; Slope of grain, 1 in 12

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	1⅔	2	2⅔	3⅓	4	4⅔	5⅓
Wane	⅝	¾	1	1¼	1½	1¾	2
Maximum permissible knots, At any point on any face	⅞	1	1⅜	1¾	2⅛	2¼	2⅜

(74) 1000 lb. c. RED AND WHITE OAK; Slope of grain, 1 in 10

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	2.0	2.4	3.2	4.0	4.8	5.6	6.4
Wane	5/6	1	1⅓	1⅔	2	2⅓	2⅔
Maximum permissible knots, At any point on any face	1¼	1½	2	2½	3	3¼	3½

(75) 900 lb. c. BLACK GUM, RED GUM, TUPELO, SOFT ELM AND CHESTNUT; Slope of grain, 1 in 14

Nominal width of face	5	6	8	10	12	14	16
Shakes, checks & splits—green	1⅔	3	2⅔	3⅓	4	4⅔	5⅓
Wane	⅝	¾	1	1¼	1½	1¾	2
Maximum permissible knots, At any point on any face	¾	⅞	1¼	1½	1⅞	2	2⅛

NOTES ON THE USE OF STRESS-GRADES

1. Working values may be used without allowance for impact up to impact of 100 per cent of loads figured. The ability of timbers to support loads is very dependent on the duration of the stress. Tests have demonstrated that the load required to break timbers in several years is about 9/16 of that required to break them as in ordinary laboratory tests. When the time is shortened still further, as in impact loading, the load required to break a timber is correspondingly increased. Approximately, this increase is 10 per cent when the time is reduced to 1/10 of the previous time. Working stresses for five-minute loading may be increased 50 per cent over those for long-time loading.

2. Working values for horizontal shear are maximum values. The maximum unit horizontal shear at any point in the length of a beam is usually calculated as being 3/2 of the average vertical shearing stress at that point. This assumption gives a very simple formula and though with checked beams loaded near the supports it is greatly in error, its continued use is recommended with certain assumptions as to the placement of live loads and the neglecting of certain loads near the supports aimed at correcting the most outstanding errors in the formula without complicating the calculations.

3. However, there is given a formula for use in conjunction with the ordinary shear formula to be used whenever the simple assumptions as to loads and their placement are not sufficiently accurate.

4. The following procedure is recommended for calculating the horizontal shear on the neutral plane in checked beams:

1. Use the following shear formula:

$$s = \frac{3R}{2bh}$$

where s = Maximum unit shear per square inch
R = Reaction in pounds
b = Breadth of beam in inches
h = Height of beam in inches

2. Use the customary allowable unit shear stress.

3. In calculating the reaction for use in the formula:
   (a) Take into account any relief to the beam under consideration resulting from load being distributed to adjacent parallel beams by flooring or other members of the construction.
   (b) Neglect all loads within the height of the beam from both supports.
   (c) If there are any moving loads, place the largest one at three times the height of the beam from the support.
   (d) Treat all other loads in the usual manner.

5. If a timber does not qualify under the above recommendations, which under certain conditions may be over-conservative, the reactions for the concentrated loads should be determined by the following equation:

$$r = \frac{10P(L-a)\left(\frac{a}{h}\right)^2}{9L\left[2+\left(\frac{a}{h}\right)^2\right]}$$

Where r = Reaction to be used as due to a Load P
L = Span in inches
a = Distance in inches from reaction to Load P
h = Height of beam in inches

6. Shear stresses for joint details may be taken as 50 per cent greater than the values for horizontal shear given in the tables.

7. Timber acquires a permanent set under long continued loading. This set with a fully loaded beam is about equal to the deflection, using the modulus of elasticity as given in the tables. In calculating ultimate deflection under long-continued loading, this factor should be recognized.

8. The working stresses for compression parallel to grain are for use on posts, struts, etc., with unsupported length not greater than ten times their least dimension. They are also for use in end bearing on compression members, as a short column or strut is more likely to fail at the end than at any other point in its length, and the variations in moisture content are greater at that point.

9. For bearing stresses on surfaces at an angle to the direction of the grain, the following (Hankinson) formula has been found to be the best for general use in timber framing:

$$N = \frac{PQ}{P\sin^2\Theta + Q\cos^2\Theta}$$

Where N = Unit compressive stress in a direction at inclination Θ with the direction of the grain.
P = Unit stress in compression parallel to the grain
Q = Unit stress in compression perpendicular to the grain
When the stress acts parallel to the grain, Θ is zero.
When the stress acts perpendicular to the grain, Θ is 90 degrees.
For $\sin^2\Theta$ and $\cos^2\Theta$ see Table 1.

10. For columns of intermediate length, the Forest Products Laboratory finds that a fourth power parabola, tangent to the Euler curve, is a conservative representation of the law controlling the strength. That is, from the short block to the long column in which the strength is dependent on stiffness, there is a falling off in ultimate strength which follows a smooth curve, very flat at first but curving sharply to become tangent to the Euler curve at two-thirds of the ultimate crushing strength.

11. For columns from

$$\frac{P}{A}=C \text{ to } \frac{P}{A}=\frac{2}{3}C:$$

$$\frac{P}{A}=C\left[l-\frac{1}{3}\left(\frac{L}{Kd}\right)^4\right]$$

Where P = Total load in pounds
A = Area in square inches
P/A = Unit compressive stress
C = Safe stress in compression parallel to grain for short columns
L = Unsupported length in inches
d = Least dimension in inches
E = Modulus of elasticity
K = The L/d at the point of tangency of the parabolic and Euler curves, at which $\frac{P}{A}=\frac{2}{3}C$

The value of K for any species and grade is $\frac{\pi}{2}\sqrt{\frac{E}{6C}}$

For unit stress L/d 10 to K, see Table 2.

12. The influence of defects on the compressive strength of columns of constant cross section decreases as the length increases. When L/d equals the value of K for the species and grade, strength-reducing factors allowable in the grade have little influence on the strength as a column. Beyond this length the investigation of the strength of columns by the Laboratory indicated that the Euler formula is quite accurate for long wood columns with pin-end connections and that the maximum load is dependent upon stiffness. In such columns, a factor of safety of 3 should be applied to values of modulus of elasticity in order to obtain safe loading.

13. The Laboratory does not, with the present data and under ordinary conditions, find justification for increasing the stresses on square-end columns over those for carefully centered pin-end columns. Tests to determine the influence of end conditions are still being made and it is probable that under special conditions higher stresses can be used.

14. For long columns, including factor of safety of 3:

$$\frac{P}{A}=\frac{\pi^2}{36}\frac{E}{\left(\frac{L}{d}\right)^2}=\frac{.274\,E}{\left(\frac{L}{d}\right)^2}$$

For unit stress $\frac{L}{d}$ K to 50, see Table 2.

15. Columns should be limited in slenderness to $L/d = 50$.

16. Post and timber grades may be applied to material smaller than sizes given by limiting the size of knots to the proportion of width of face permitted on sizes given.

17. For direct tension the same values as for extreme fiber stress in bending may be used. Straight grained-wood has greater resistance to tension than to any other kind of stress, and it has been difficult to design joints that will develop the full tensile strength. The availability of ring-connectors now largely eliminates this difficulty.

18. Grades of joists or beams may be used for members in longitudinal tension, such as bottom chords or tension members of trusses, but grade limitations which apply to the center portions of joists and beams should be applied throughout the entire length of pieces subjected to longitudinal tension.

19. The provisions of the joist and plank grades are such that material graded on them may be used on edge as joist or rafters, or flat, as scaffold plank or factory flooring, and working stresses for these grades may be applied to such material used with wide faces either vertical or horizontal. Joist and plank grades apply to material not thicker than four inches. Material thicker than four inches, for use in bending, should be graded on beam and stringer grades. In such material with loads applied to the wide face, the knot limitations for this face are those for the narrow face as given in the rules.

20. Material to be used for such purposes as caps, bridge ties, etc., where strength in bending is a factor, should be specified in beam and stringer grades, although of shape more commonly considered as of timber grades, as the method of measuring knots in post and timber grades makes it impracticable to assign bending stresses to them. Caps and bridge ties are often square or have horizontal faces wider than the vertical faces, in contrast to beams and stringers, in which the narrow faces are horizontal faces and the wide faces are vertical, and care should be exercised that knot limitations are applied to the proper faces.

21. In railway stringers of two span lengths, it should be specified that grade factors throughout the center two-thirds be limited as in the middle third or middle half of a single span stringer, for the maximum moment will be over the center support, and although the full positive moment would not be developed in either span as long as there was resistance to negative moment over the center support, there might be circumstances in which full positive moment of resistance at the centers of the two spans would be desirable.

22. In material used over three or more spans, or subject to varying bending moments, such as full length sills of wood under-framed cars, grade limitations should be applied throughout the entire length as in the middle third or middle half of joist and plank and beams and stringers.

23. The strength of timbers and posts in round form is greater than would be expected from the ordinary engineering formulas. The strength, stiffness and shearing value in bending of round timbers of any species may be assumed to be identical with that of square timbers of the same grade and cross-sectional area. Tapered timbers should be assumed as of uniform diameter, the point of measurement being one-third the span from the small end, but the diameter should not be assumed to be more than one and one-half times the end diameter.

24. The strength of round columns may be considered the same as that of square columns of the same cross-sectional area. In long tapered columns the strength may be assumed as identical with that of a square column of the same length, and of cross-sectional area equal to that of the round timber measured at a point one-third its length from the small end. The stress at the small end must not exceed the allowable stress for short columns.

25. Detailed studies on the strength of timber in round form are available in Reports 180 and 181 of the National Advisory Committee for Aeronautics on "The Influence of the Form of a Wooden Beam on Its Stiffness and Strength."

26. In determining working stresses, the Forest Products Laboratory has considered both elastic limit and breaking strength. Elastic limit, however, is more variable and less definite than ultimate strength, and the latter is taken as the more dependable basis for the determination of safe working stresses.

27. The factor of safety at a given working stress varies materially with the duration of the stress. At the recommended working stresses, the average timber in buildings has a factor of safety of *6 on impact loading, 4 under five-minute loads and 2¼ under long-time loading, with a minimum factor of safety of 2 on 75 per cent of the pieces under long-time loading, while about 1 piece in 100, of very light weight and with maximum defects for the grade, would be expected to break at 1½ times the recommended stress under loading of approximately ten years' duration. The factor of safety on new timbers in bridge work is about 1/7 greater than the above values.

TABLE I.—*$Sin^2\Theta$ and $Cos^2\Theta$ for Hankinson Formula*

$Sin^2\Theta$	Θ	$Cos^2\Theta$	$Sin^2\Theta$	Θ	$Cos^2\Theta$
.00000	0	1,00000	.50000	45	.50000
.00760	5	.99240	.58682	50	.41318
.03015	10	.96985	.67101	55	.32899
.06698	15	.93302	.75000	60	.25000
.11698	20	.88302	.82140	65	.17860
.17860	25	.82140	.88302	70	.11698
.25000	30	.75000	.93302	75	.06698
.32899	35	.67101	.96985	80	.03015
.41318	40	.58682	.99240	85	.00760
.50000	45	.50000	1.00000	90	.00000

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* If impact stresses are neglected when less than 100 per cent of the live load producing them, the factor of safety for such loads would be reduced from 6 to a minimum of 3.

TABLE 2.—*Unit Compression Stresses for Standard Stress Grades*

Short Column Stress	Modulus of Elasticity	K	Stress at Ratio of Length to Least Dimension (L/d) 10	12	14	16	18	20	25	30	35	40	45	50
1300	1,300,000	20.3	1300	1247	1203	1132	1032	892	570	396	291	223	176	142
	1,600,000	22.5	1300	1265	1235	1190	1123	1030	701	487	358	274	216	175
1200	1,200,000	20.3	1200	1151	1110	1045	953	823	526	365	268	206	162	132
	1,300,000	21.1	1200	1158	1122	1068	989	827	570	396	291	223	176	142
	1,500,000	22.7	1200	1169	1142	1102	1042	959	658	457	336	257	203	164
	1,600,000	23.4	1200	1172	1148	1112	1060	986	701	487	358	274	216	175
1100	1,200,000	21.2	1100	1063	1031	981	910	810	526	365	268	206	162	132
	1,300,000	22.1	1100	1068	1041	999	938	854	570	396	291	223	176	142
	1,500,000	23.7	1100	1076	1055	1024	978	914	658	457	336	257	203	164
	1,600,000	24.4	1100	1078	1060	1032	991	935	701	487	358	274	216	175
1000	1,200,000	22.2	1000	972	947	910	856	780	526	365	268	206	162	132
	1,300,000	23.1	1000	976	955	923	877	813	570	396	291	223	176	142
	1,500,000	24.8	1000	982	966	942	908	859	658	457	336	257	203	164
	1,600,000	25.6	1000	984	970	948	918	876	697	487	358	274	216	175
900	1,200,000	23.4	900	879	861	834	795	740	526	365	268	206	162	132
	1,600,000	27.0	900	888	878	863	841	810	680	487	358	274	216	175
	1,000,000	21.4	900	870	845	806	750	674	420	304	223	170	134	109
800	1,000,000	22.7	800	779	762	734	694	639	438	304	224	171	135	110

Appendix C

(3) OVERHEAD WOOD OR COMBINATION WOOD AND METAL HIGHWAY BRIDGES

R. P. Hart, Chairman, Sub-Committee; F. H. Cramer, R. W. Gustafson, C. J. Hogue, W. A. Oliver, G. W. Rear, H. T. Rights, W. R. Wilson.

The plan presented by the Committee last year as Proposed Recommended Practice has been further refined and is now submitted with the recommendation that it be adopted as Recommended Practice and printed in the Manual.

It is also recommended that the subject be continued with the view of developing another plan to provide for long panels with metal stringers, sidewalk details and other features.

Appendix D

(4) DESIGN OF WOOD TRESTLES FOR HEAVY LOADINGS

H. M. Church, Chairman, Sub-Committee; G. M. Cornell, S. F. Grear, J. A. Newlin, G. W. Rear, W. R. Roof, W. J. Ryan, D. W. Smith, W. R. Wilson.

In last year's report of this Sub-Committee there was presented for discussion a proposed plan for open deck timber trestle for E-72 loading. During the past year criticism, some adverse and some favorable, has been presented and changes have been made in the plan as follows:

1. The longitudinal bracing system has been changed to conform to that used on lighter trestles as now included in the Manual, except as follows:

    1. All bracing is fastened with two bolts one inch in diameter at each post or pile.
    2. Pile trestles are to have longitudinal cross bracing in every second panel instead of every third panel as shown for lighter design.
    3. The height of pile bents on which longitudinal cross bracing can be omitted has been reduced from 15 feet to 10 feet from top of tie to ground.

While the Committee feels that some change is desirable in the design of the longitudinal bracing more time is required for study and it is thought that the present bracing, revised as above, will answer until thorough investigation can be made to determine the most satisfactory design.

2. The lap chord design has been revised to make the stringer layout symmetrical about the center line of trestle. This arrangement will facilitate framing and will permit symmetrical bolt holes in the cap.

3. The steel cap design has been eliminated, pending further study.

The table of stresses accompanying the drawing has been revised to correct a few minor errors which were discovered.

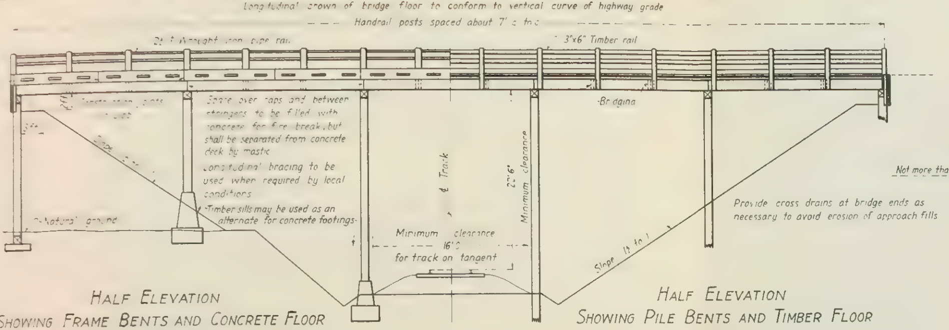
In last year's report there was included a plan of proposed recommended practice for walks and platforms on open deck trestles. No adverse criticism of this design has been received and the only changes made in the drawing have been the addition of a note relative to clearances required by law.

This year the Committee is presenting as information, with the idea of inclusion next year in the Manual, a plan for ballasted deck trestles for E-72 loading. The table of stresses for this design is also presented herewith and is to be considered as a part of the

Unit shear - lbs./sq. in. = $\frac{3}{2} \; \frac{R}{A}$

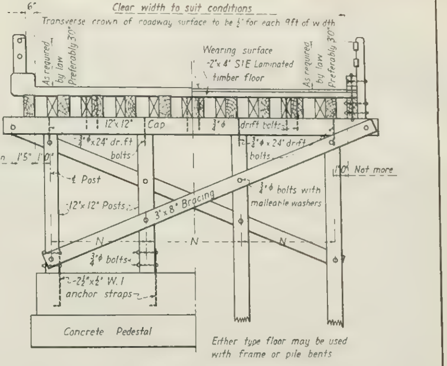
ASSUMPTIONS:

L = Distance C to C bents for bearing on caps
= Distance face to face of caps + 6" for s
bending and shear (Assume 14" cap)
W = Total Dead Load per Lin. Ft. Track:
Rail & fastenings = 200 #/lin. ft.
Ties 8"x8"x10'-0" @ 12" ctrs. = 266 #/lin


Longitudinal crown of bridge floor to conform to vertical curve of highway grade
Handrail posts spaced about 7' c to c
2½" wrought iron pipe rail
3"x6" Timber rail
Space over caps and between stringers to be filled with concrete for fire break, but shall be separated from concrete deck by mastic
Longitudinal bracing to be used when required by local conditions
Timber sills may be used as an alternate for concrete footings
Natural ground
Bridging
℄ Track
22'6" Minimum clearance
Minimum clearance 16'0" for track on tangent
Provide cross drains at bridge ends as necessary to avoid erosion of approach fills
Slope 1½ to 1

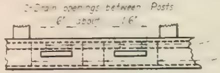
HALF ELEVATION
SHOWING FRAME BENTS AND CONCRETE FLOOR

HALF ELEVATION
SHOWING PILE BENTS AND TIMBER FLOOR

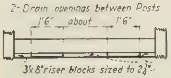

6"
Clear width to suit conditions
Transverse crown of roadway surface to be ⅛" for each 9ft of width
As required by law Preferably 3'0"
Wearing surface
2"x4" S1E Laminated timber floor
12"x12" Cap
¾"ϕ drift bolts
¾"ϕx24" drift bolts
Not more than 1'5" 1'0"
℄ Post
12"x12" Posts
3"x8" Bracing
¾"ϕ bolts with malleable washers
1'0" Not more
N
¾"ϕ bolts
2-2½"x½" W.I anchor straps
Concrete Pedestal
Either type floor may be used with frame or pile bents

HALF FRAME BENT AND CONCRETE FLOOR

HALF PILE BENT AND TIMBER FLOOR

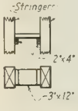


ELEVATION OF CURB

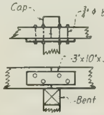


3"x8" riser blocks sized to 2⅝"

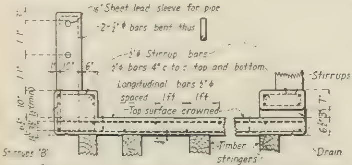
ELEVATION OF GUARD TIMBER



BRIDGING

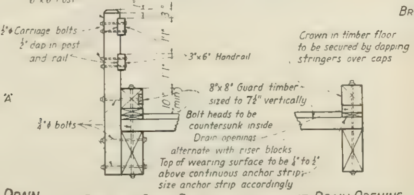


OUTSIDE STRINGER SPLICE



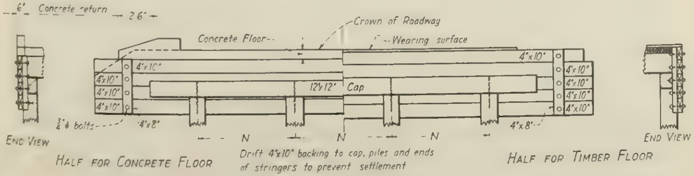
SECTION OF CURB AT POST   SECTION OF CURB AT DRAIN

DETAIL OF CONCRETE SLAB AND HANDRAIL POST


1"
6"x6" Post
½"ϕ Carriage bolts
½" dap in post and rail
3"x6" Handrail
8"x8" Guard timber sized to 7½" vertically
¾"ϕ bolts
Bolt heads to be countersunk inside
Drain openings alternate with riser blocks
Top of wearing surface to be ¼" to ½" above continuous anchor strip; size anchor strip accordingly
Crown in timber floor to be secured by dapping stringers over caps

AT POST AND RISER BLOCK   AT DRAIN OPENING

DETAIL OF TIMBER FLOOR AND HANDRAIL POST



Drift 4"x10" backing to cap, piles and ends of stringers to prevent settlement

BACKING FOR END BENT

Spacing c to c of Bents	Size of Stringers Maximum Spacing 2'3" c to c	Maximum Spacing N Concrete Floor	Maximum Spacing N Timber Floor
13'	6"x15" or 7"x14"	7'6"	7'6"
14'	7"x15" or 6"x16"	7'6"	7'6"
15'	6"x16"	7'6"	7'6"
16'	6"x17" or 7"x16"	7'6"	7'6"
17'	6"x18" or 7"x16"	7'0"	7'6"
18'	8"x16" or 6"x18"	7'0"	7'6"
19'	8"x16" or 7"x18"	7'0"	7'6"
20'	7"x18"	6'6"	7'6"
21'	7"x18" or 9"x16"	6'6"	7'6"
22'	8"x18" or 10"x16"	6'6"	7'6"
23'	8"x18" or 10"x16"	6'0"	7'6"
24'	9"x18"	6'0"	7'6"
25'	9"x18"	6'0"	7'0"
26	8"x20" or 10"x18"	5'6"	7'0"
27'	9"x20" or 10"x18"	5'6"	7'0"
28'	9"x20"	5'6"	7'0"
29'	9"x20"	5'0"	7'0"
30'	10"x20"	5'0"	6'6"
31'	10"x20"	5'0"	6'6"
32'	10"x22"	5'0"	6'6"
33'	10"x22"	4'6"	6'0"
34'	10"x22"	4'6"	6'0"
35'	10"x22"	4'6"	6'0"
36'	10"x24"	4'6"	6'0"

Note:- Stresses in stringers computed for span = face to face of bents plus six inches.

Loading .... A. R. E. A. H-15 Truck.

Timber. .... Stringers 1600 lb "f", other timber 1200 lb. "c", structural grade, conforming to A.R.E.A specifications and treated with an approved preservative
Working stresses (lbs. per sq in) 1400 bending, 240 compression across grain.
Stringers to be sized to a uniform depth one half inch less than nominal depth for a length of two feet from each end only
All field holes and field cuts to be treated with preservative.
Holes to be bored the same size as bolts to be placed therein
Handrails to be painted white.

Concrete .... 28 day strength 3000 lb for slabs and 2000 lb. for footings
Working stresses and workmanship to conform to A.R.E.A specifications.
Bevel 90° edges one inch.
Size and depth of footings to be made to suit soil conditions

Reinforcing Steel....... Deformed section, new billet stock, structural grade

Wearing Surface...... One of the following,
1 One and one half inch asphalt plank, laid longitudinally with roadway, in hot pitch.
2. Asphalt mastic one and one half inches or more in thickness.
3. Timber plank laid diagonally with roadway. Plank to be surfaced to uniform thickness of not less than one and one half inches

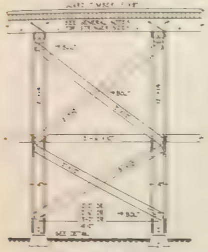
RECOMMENDED PRACTICE
FOR
OVERHEAD WOOD HIGHWAY BRIDGE
H-15 LOADING
A. R. E. A.

(B)

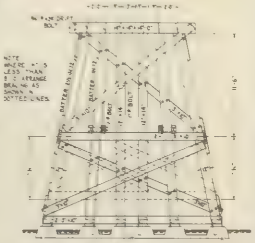
Total load
Cross-section - sq. in. - nominal size
Unit shear - lbs./sc. in. = $\frac{3}{2} \frac{R}{A}$
Cross-section - sq. in. - dressed size
Unit shear - lbs./sq. in. = $\frac{3}{2} \frac{R}{A}$

ASSUMPTIONS:

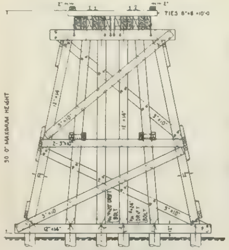
L = Distance C to C bents for bearing on caps
= Distance face to face of caps + 6" for s
bending and shear (Assume 14" cap)
W = Total Dead Load per Lin. Ft. Track:
Rail & fastenings = 200 #/lin. ft.
Ties 8"x8"x10'-0" @ 12" ctrs. = 266 #/lin.



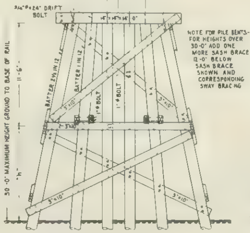
ELEVATION



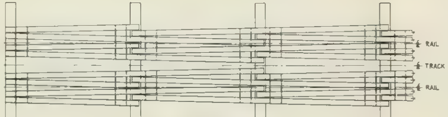
FRAME BENT ON CONCRETE PEDESTAL



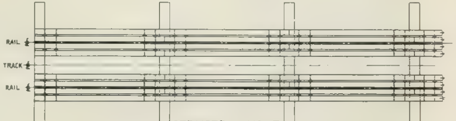
FRAME BENT ON PILES



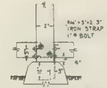
PILE BENT



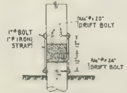
STRINGER LAYOUT
LAP CHORD DESIGN



STRINGER LAYOUT
BUTT CHORD DESIGN



PEDESTAL DETAIL
WITH NEAR
BRACE REMOVED



ANCHOR DETAIL
FOR FRAME BENT
ON PILE FOUNDATION
TO BE USED WHERE NECESSARY

GENERAL NOTES -

SIZE OF STRINGERS TO BE DETERMINED FROM ATTACHED TABLE OF STRESSES WITH CONSIDERATION FOR SPAN LENGTH AND TIMBER STRESS GRADE STRINGERS SHOWN DRESSED IN DEPTH TO 1" LESS THAN NOMINAL SIZE BUT IF DESIRED THEY CAN BE DAPPED OVER CAPS STRINGERS SHOWN WITH SPACERS BETWEEN THEM BUT IF TREATED TIMBER IS USED SPACERS MAY BE OMITTED AND STRINGERS SET TIGHT STRINGERS SHOWN TWO PANEL LENGTH BUT IN LAP CHORD DESIGN SINGLE PANEL LENGTH STRINGERS MAY BE USED IF DESIRED

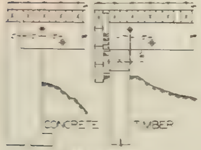
IF DESIRABLE BENTS MAY BE SPACED 11'-9" 12'-3" 12'-9" OR 3'-9" APART TO ASSURE THAT SPAN LENGTHS WILL NOT OVERRUN STANDARD STRINGER LENGTHS OR TO ALLOW FOR INCREASED LENGTH ON CURVES

TIMBER DIMENSIONS ARE NOMINAL SIZES

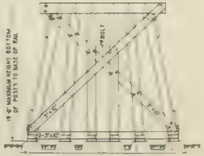
LONGITUDINAL GIRTS TO BE FASTENED AT PILES OR POSTS AS SHOWN IN DETAIL "A" ON PLANS FOR E-60 LOADING LONGITUDINAL GIRTS MUST BE CARRIED TO BANK AND SECURELY FASTENED TO BENT NEAR GROUND

TIES ARE SURFACED TO UNIFORM DEPTH AND ARE NOT DAPPED

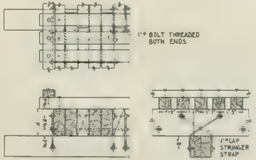
VIEWS WITH TITLES "ELEVATION" "FRAME BENT ON CONCRETE PEDESTAL" "FRAME BENT UP TO 19 FT" "FRAME BENT ON PILES" "PILE BENT", "STRINGER LAYOUT LAP CHORD DESIGN" AND "STRINGER LAYOUT BUTT CHORD DESIGN" ARE DRAWN TO HALF SCALE OF OTHER VIEWS WITH EXCEPTION OF "LONGITUDINAL BRACING DIAGRAM" WHICH IS NOT DRAWN TO SCALE



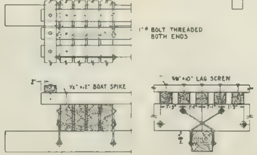
BULKHEADS



FRAME BENT UP TO 19 FT

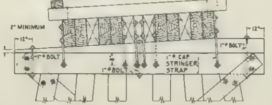


CAP DETAIL-LAP CHORD DESIGN

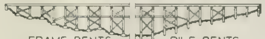


CAP DETAIL - BUTT CHORD DESIGN

NOTE ON SUPPLEMENTARY CAP -
TO BE USED IF ELEVATION IS NOT
FRAMED IN PILE CUT-OFF.



SUPPLEMENTARY CAP FOR SUPERELEVATION



FRAME BENTS
TRESTLES TO HAVE
LONGITUDINAL
BRACING FOR
ALL HEIGHTS

PILE BENTS
TRESTLES OVER 10'-0" IN HEIGHT
BASE OF RAIL TO GROUND SHALL
HAVE LONGITUDINAL CROSS
BRACING EVERY 2ND PANEL

LONGITUDINAL BRACING DIAGRAM

RECOMMENDED PRACTICE
FOR
6 PILE OR 6 POST
OPEN DECK TRESTLE
E-72 LOADING
AREA.

All Loads in lbs. per track All Moments in foot-lbs. per track
Panel length C to C of bents
No. and size of stringers
Dead load per ft. of track Rail, ties, and guard rail Stringers
Total dead load
Reaction on bent Dead load Live load
Total
Kind of bent
No. of piles or posts
Size of piles or posts
Total area of piles or posts - Sq. in.
Unit bearing stress on piles or posts - lbs./sq.
Load in tons on piles or posts
Bearing - stringers to caps Area sq. in. - 14" cap
Bearing stress - lbs./sq. in. 14" cap
Area sq. in. - 16" cap
Bearing stress - lbs./sq. in. 16" cap
Bending in stringers Dead load moment - ft. lbs./track Live " " " " "
Total " " " "
Section modulus - Nominal size
Bending stress - lbs./sq. in. -Nominal s
Section modulus - Dressed size
Bending stress - lbs./sq.in. - Dressed s
Longitudinal shear - Standard formula - First driver at quarter point. Dead load = WL/2 Live load
Total load
Cross-section - sq. in. - Nominal size
Unit shear - lbs./sq. in = $\frac{3}{2}\ \frac{R}{A}$
Cross-section - sq. in. - dressed size
Unit shear - lbs./sq. in = $\frac{3}{2}\ \frac{R}{A}$
Longitudinal shear based on tests by Forest Products Laboratory. First driver at 3 x ht. of beam from support. Dead load = $\frac{W\ (L-2h)}{2}$ Live load
Total load
Cross-section - sq. in. - nominal size
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$
Cross-section - sq. in. - dressed size
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$
Longitudinal shear based on tests by Forest Products Laboratory using revised shear formula. First driver at 3 x ht. of beam fro support. Dead load = $\frac{W\ (L-2h)}{2}$ Live load = $\frac{10}{9}\ \frac{P}{L}\ \frac{(L-X)\ \left[\frac{X}{h}\right]^2}{2 + \left[\frac{X}{h}\right]^2}$
Total load
Cross-section - sq. in. - nominal size
Unit shear - lbs./sc. in. = $\frac{3}{2}\ \frac{R}{A}$
Cross-section - sq. in. - dressed size
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$

ASSUMPTIONS:

L = Distance C to C bents for bearing on caps
= Distance face to face of caps + 6" for s
bending and shear (Assume 14" cap)
W = Total Dead Load per Lin. Ft. Track:
Rail & fastenings = 200 #/lin. ft.
Ties 8"x8"x10'-0" @ 12" ctrs. = 266 #/lin

OPEN DECK TRESTLE
COMPARISON OF UNIT STRESSES IN PROPOSED TIMBER TRESTLE FOR COOPER CLASS E-72 LOADING, NO IMPACT

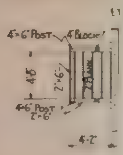
All Loads in lbs. per track
All Moments in foot-lbs. per track

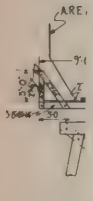
Panel length C to C of bents	12'		12'		12'		12'-6"		13'		13'		13'		14'		14'		14'		14'	
No. and size of stringers	8-8" x 16"		6-10" x 16"		6-9" x 18"		8-8" x 16"		6-9" x 18"		8-10" x 16"		6-10" x 18"		8-10" x 16"		8-9" x 18"		6-10" x 18"		6-10" x 20"	
Dead load per ft. of track																						
Rail, ties, and guard rail	499		499		499		499		499		499		499		499		499		499		499	
Stringers	426		400		404		426		404		534		450		534		540		450		500	
Total dead load	925		899		903		925		903		1033		949		1033		1039		949		999	
Reaction on bent																						
Dead load	11100		10800		10830		11560		11740		13450		12320		14490		14550		13290		13990	
Live load	168000		168000		168000		173000		177200		177200		177200		187500		187500		187500		187500	
Total	179100		178800		178800		184560		188940		190650		189520		201990		202050		200790		201490	
Kind of bent	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame
No. of piles or posts	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Size of piles or posts	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14
Total area of piles or posts - sq. in.	770	840	770	840	770	840	924	1008	924	1008	924	1008	924	1008	924	1008	924	1008	924	1008	924	1008
Unit bearing stress on piles or posts - lbs./sq. in.	233	213	232	213	232	213	200	183	204	188	206	189	205	188	219	201	219	201	218	200	218	200
Load in tons on piles or posts	17.9	17.9	17.9	17.9	17.9	17.9	15.4	15.4	15.7	15.7	15.9	15.9	15.8	15.8	16.8	16.8	16.8	16.8	16.7	16.7	16.7	16.7
Bearing - stringers to caps																						
Area sq. in. - 14" cap	896		840		756		896		756		1120		840		1120		1008		840		840	
Bearing stress - lbs./sq. in. 14" cap	200		213		237		206		250		170		226		181		201		239		240	
Area sq. in. - 16" cap	1024		960		864		1024		864		1280		960		1280		1152		960		960	
Bearing stress - lbs./sq. in. 16" cap	176		186		207		180		219		149		198		158		176		209		210	
Bending in stringers																						
Dead load moment - ft. lbs./track	14850		14450		14500		16200		17200		19650		18100		23000		23100		21100		22200	
Live " " " " "	252000		252000		252000		280000		306000		306000		306000		360000		360000		360000		360000	
Total " " " "	266850		266450		266500		296200		323200		325650		324100		383000		383100		381100		382200	
Section modulus - Nominal size	2730		2560		2916		2730		2916		3415		3240		3415		3888		3240		4000	
Bending stress - lbs. sq. in. - Nominal size	1170		1250		[illegible]		1305		1330		1150		1200		1350		1180		1395		1150	
Section modulus - Dressed size	2560		2400		2756		2560		2756		3200		3060		3200		3680		3060		3710	
Bending stress - lbs./sq.in. - Dressed size	[illegible]		1330		[illegible]		1390		1410		1250		1270		1435		1250		1490		1235	
Longitudinal shear - Standard formula - First driver at quarter point.																						
Dead load = WL/2	5250		5100		5120		5470		5560		6380		5850		6900		6920		6330		6660	
Live load	76100		76100		76100		77500		78800		78800		78800		81000		81000		81000		81000	
Total load	81350		81200		81220		82970		84360		85180		84650		87900		[illegible]		[illegible]		87660	
Cross-section - sq. in. - Nominal size	1024		960		972		1024		972		1280		1080		1280		1296		1080		1200	
Unit shear - lbs./sq. in = $\frac{3}{2}\ \frac{R}{A}$	119		127		125		122		130		100		118		103		102		121		109	
Cross-section - sq. in. - dressed size	[illegible]		930		945		992		945		1240		1050		1240		1260		1050		1170	
Unit shear - lbs./sq. in = $\frac{3}{2}\ \frac{R}{A}$	123		131		129		126		134		103		121		106		105		125		112	
Longitudinal shear based on tests by Forest Products Laboratory. First driver at 3 x ht. of beam from support.																						
Dead load = $\frac{W\ (L-2h)}{2}$	4000		3890		3770		4230		4210		5000		4420		5510		5360		4900		5000	
Live load	61400		61400		55000		64800		62300		68100		62300		73700		68400		68400		87500	
Total load	65400		65290		58770		69030		66510		73100		66720		79210		73760		73300		92500	
Cross-section - sq. in. - nominal size	1024		960		972		1024		972		1280		1080		1280		1296		1080		1200	
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$	96		102		91		101		103		86		[illegible]		93		85		102		116	
Cross-section - sq. in. - dressed size	992		930		945		992		945		1240		1050		1240		1260		1050		1170	
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$	99		105		93		105		106		89		96		96		88		105		119	
Longitudinal shear based on tests by Forest Products Laboratory using revised shear formula. First driver at 3 x ht. of beam from support.																						
Dead load = $\frac{W\ (L-2h)}{2}$	4000		3890		3770		4230		4210		5000		4420		5510		5360		4900		5000	
Live load = $\frac{10}{9}\ \frac{P}{L}\ \frac{(L-X)\left[\frac{x}{h}\right]^2}{2+\left[\frac{x}{h}\right]^2}$	58100		58100		51600		61500		59100		64800		59100		70600		65500		65500		60000	
Total load	62100		61990		55370		65730		63310		69800		63520		76110		70860		70400		65000	
Cross-section - sq. in. - nominal size	1024		960		972		1024		972		1280		1080		1280		1296		1080		1200	
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$	91		97		85		96		[illegible]		82		88		89		82		98		81	
Cross-section - sq. in. - dressed size	992		930		945		992		945		1240		1050		1240		1260		1050		1170	
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$	94		100		88		99		101		85		[illegible]		92		84		101		83	

ASSUMPTIONS:

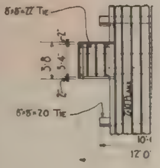
L = Distance C to C bents for bearing on caps
= Distance face to face of caps + 6" for stringer bending and shear (Assume 14" cap)
W = Total Dead Load per Lin. Ft. Track:
Rail & fastenings = 200 #/lin. ft.
Ties 8"x8"x10'-0" @ 12" ctrs. = 286 #/lin. ft.

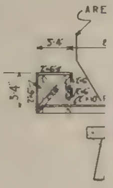
Outside Guard Rail 2 pcs. 5" x 8"
All Timber @ 5#/FBM
h = Height stringer in feet
P = Wt. on one driving axle = 72000#
x = Distance of load from support in feet.
Dressed size = Nominal size less 1/2" in depth.





DETA





DETAIL

COOPERS E-72 LOADING
A.R.E.A.

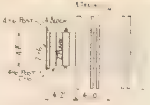
Cross - Section - sq. in. - dressed size

Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$

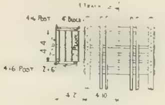
ASSUMPTIONS:

L = Distance C. to C. bents for b
= Distance face to face of caps
bending and shear. (Assume

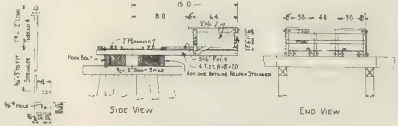
W = Total Dead Load per lin. ft.
Rail and fastenings = 200
Ballast = 120 #/cu. ft.
Timber = 5 #/FBM



PLAN



PLAN

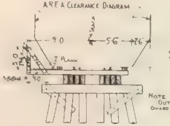


HOOK BOLT

SIDE VIEW

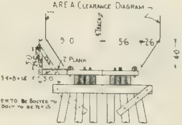
END VIEW

TRACK CAR PLATFORM – SCHEME A
USING LONG TIES

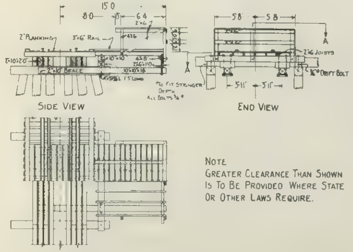


ELEVATION
DETAILS OF REFUGE PLATFORM
USING LONG TIES

NOTE
OUTRIGGER TO BE BOLTED TO
GUARD RAIL BOLT TO BE ½×15



ELEVATION
DETAIL OF REFUGE PLATFORM
ALTERNATE PLAN USING OUTRIGGERS



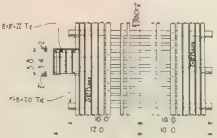
SIDE VIEW

END VIEW

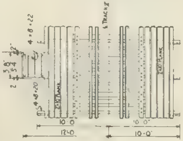
SECTION "A–A"

TRACK CAR PLATFORM – SCHEME B
USING HANGERS

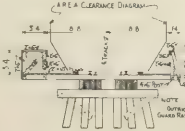
NOTE
GREATER CLEARANCE THAN SHOWN
IS TO BE PROVIDED WHERE STATE
OR OTHER LAWS REQUIRE.



PLAN



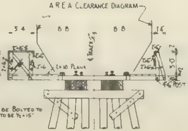
PLAN



NOTE
OUTRIGGER TO BE BOLTED TO
GUARD RAIL BOLT TO BE ½×15"

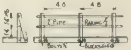
ELEVATION

DETAIL OF WALK AND BARREL PLATFORM
USING LONG TIES



ELEVATION

DETAIL OF WALK AND BARREL PLATFORM
ALTERNATE PLAN USING OUTRIGGERS

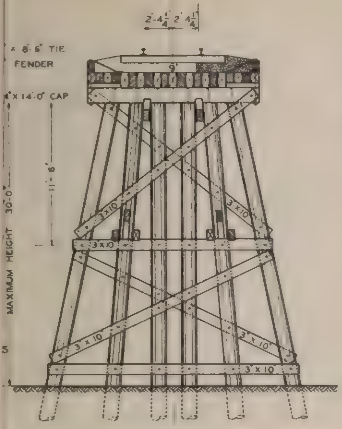


NOTE
ALTERNATE SCHEME OF RAILING USING 2" PIPE
SPACED AS SHOWN MAY BE USED WITH LONG
TIES OR OUTRIGGERS

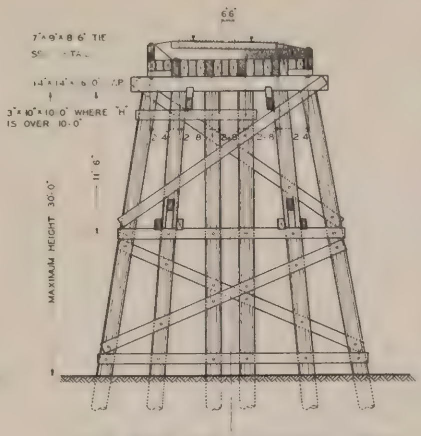
RECOMMENDED PRACTICE
FOR

WALKS AND PLATFORMS ON OPEN DECK TRESTLES

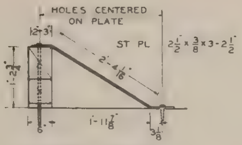
ALL LOADINGS
A.R.E.A



PILE BENT



PILE BENT FOR ELEVATED TRACK



FENDER DETAIL
FOR ELEVATED TRACK

BOAT SPIKE

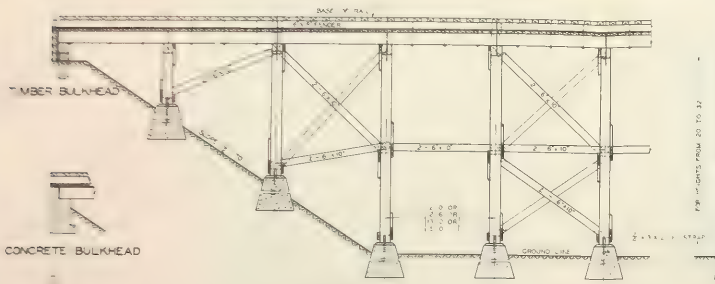
RECOMMENDED PRACTICE
6 PILE OR 6 POST
BALLASTED DECK TRESTLE
COOPERS E-72 LOADING
A.R.E.A.

Cross - Section - sq. in. - dressed size

Unit Shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$

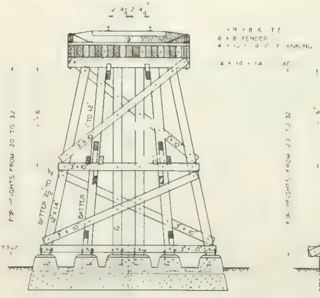
ASSUMPTIONS:

L = Distance C. to C. bents for b
= Distance face to face of caps
bending and shear. (Assume
W = Total Dead Load per lin. ft.
Rail and fastenings = 200
Ballast = 120 #/cu. ft.
Timber = 5 #/FBM

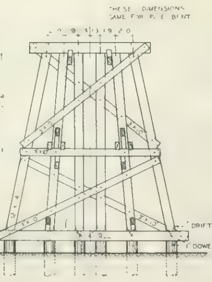


CONCRETE BULKHEAD

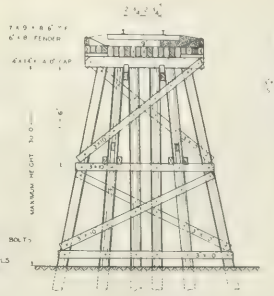
ELEVATION



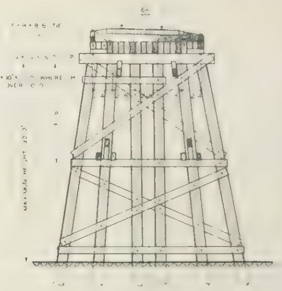
FRAME BENT ON CONCRETE PEDESTAL



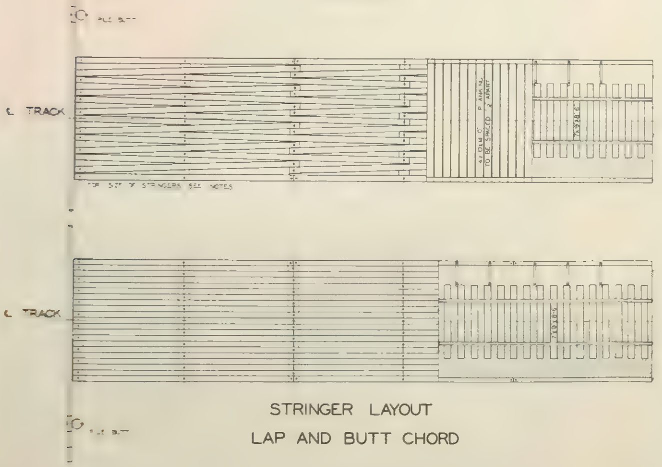
FRAME BENT ON PILING



PILE BENT

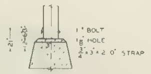


PILE BENT FOR ELEVATED TRACK

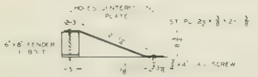


STRINGER LAYOUT

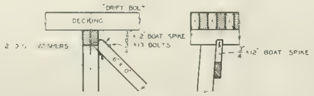
LAP AND BUTT CHORD



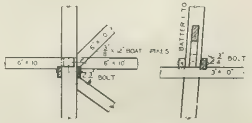
PEDESTAL DETAIL



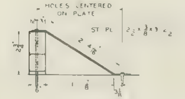
FENDER DETAIL



LONGITUDINAL BRACING AT CAP



LONGITUDINAL BRACING AT INTERMEDIATE JOINTS



FENDER DETAIL
FOR ELEVATED TRACK

RECOMMENDED PRACTICE

6 PILE OR 6 POST
BALLASTED DECK TRESTLE

COOPERS E-72 LOADING
A.R.E.A.

All loads in lbs. per track
All Moments in foot-lbs. per track

Panel length C to C of bents
No. and size of stringers
Dead load per ft. of track Above stringers Stringers
Total dead load
Reaction on bent Dead load Live load
Total
Kind of bent
No. of piles or posts
Size of piles or posts
Total area of piles or posts - sq. in.
Unit bearing stress on piles or posts - lbs./sq.in.
Load in tons on piles or posts
Bearing - Stringers to caps
Area sq. in. - 14" cap
Bearing stress - lbs./sq. in. 14" cap
Area sq. in. - 16" cap
Bearing stress - lbs./sq. in. 16" cap
Bending in stringers Dead load moment - ft. lbs./ track Live " " " " "
Total " " " "
Section mondulus - nominal size
Bending stress - lbs./sq. in. - nominal size
Section mondulus - dressed size
Bending stress - lbs./sq. in. - dressed size
Longitudinal shear - Standard formula - First driver at quarter point. Dead load = WL/2 Live load
Total load
Cross - Section - sq. in. - nominal size
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$
Cross - Section - sq. in. - dressed size
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$
Longitudinal shear based on tests by Forest Products Laboratory. First driver at 3 x ht. of beam from support. Dead load = $\frac{W(L-2h)}{2}$ Live load
Total load
Cross - Section - sq. in. - nominal size
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$
Cross - Section - sq. in. - dressed size
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$
Longitudinal shear based on tests by Forest Products Laboratory using revised shear formula. First driver at 3 x ht. of beam from support. Dead load = $\frac{W(L-2h)}{2}$ Live load = $\frac{10}{9}\ \frac{P}{L}\ \frac{(L-X)\left[\frac{X}{h}\right]^2}{2+\left[\frac{X}{h}\right]^2}$
Total load -
Cross - Section - sq. in. - nominal size
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$
Cross - Section - sq. in. - dressed size
Unit shear - lbs./sq. in. = $\frac{3}{2}\ \frac{R}{A}$

ASSUMPTIONS:

L = Distance C. to C. bents for b
= Distance face to face of caps
bending and shear. (Assume
W = Total Dead Load per lin. ft.
Rail and fastenings = 200
Ballast = 120 #/cu. ft.
Timber = 5 #/FBM

All loads in lbs. per track
All Moments in foot-lbs. per track

BALLAST DECK TRESTLE
COMPARISON OF UNIT STRESSES IN PROPOSED TIMBER TRESTLES FOR COOPER CLASS E-72 LOADING, NO IMPACT

Panel length C to C of bents	12'-0"		12'-0"		12'-6"		13'-0"		13'-0"		13'-0"		13'-0"		15'-0"		15'-0"		15'-0"		15'-0"	
No. and size of stringers	14-7" x 14"		12-7" x 16"		12-8" x 16"		14-7" x 16"		12-8" x 16"		10-10" x 16"		10-9" x 18"		14-8" x 16"		12-10" x 16"		12-9" x 18"		10-10" x 18"	
Dead load per ft. of track																						
Above stringers	2310		2310		2310		2310		2310		2310		2310		2310		2310		2310		2310	
Stringers	570		560		640		650		640		670		675		750		800		810		750	
Total dead load	2880		2870		2950		2960		2950		2980		2985		3060		3110		3120		3060	
Reaction on bent																						
Dead load	34600		34500		36900		38500		38400		38800		38800		46000		46600		46800		46000	
Live load	168000		168000		173000		177200		177200		177200		177200		197000		197000		197000		197000	
Total	202600		202500		209900		215700		215600		216000		216000		243000		243600		243800		243000	
Kind of bent	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame	Pile	Frame
No. of piles or posts	6	6	6	6	6	6	7	6	7	6	7	6	7	6	7	6	7	6	7	6	7	6
Size of piles or posts	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12X14	14"D	12x14	14"D	12x14	14"D	12x14	14"D	12x14
Total area of piles or posts - sq. in.	924	1008	924	1008	924	1008	1075	1008	1075	1008	1075	1008	1075	1008	1075	1008	1075	1008	1075	1008	1075	1008
Unit bearing stress on piles or posts - lbs./sq.in.	219	201	219	201	227	208	200	214	200	214	201	214	201	214	226	241	226	242	226	242	226	241
Load in tons on piles or posts	16.9	16.9	16.9	16.9	17.5	17.5	15.4	18.0	15.4	18.0	15.4	18.0	15.4	18.0	17.4	20.2	17.4	20.3	17.4	20.3	17.4	20.2
Bearing - Stringers to caps																						
Area sq. in. - 14" cap	1176		980		1120		1176		1120		1120		1008		1344		1400		1260		1120	
Bearing stress - lbs./sq. in. 14" cap	173		207		187		183		192		193		214		181		174		193		217	
Area sq. in. - 16" cap	1344		1220		1280		1344		1280		1280		1152		1536		1600		1440		1280	
Bearing stress - lbs./sq. in. 16" cap	151		181		164		160		168		169		187		158		152		169		190	
Bending in stringers																						
Dead load moment - ft. lbs./ track	46200		46100		51600		56200		56000		56500		56600		78500		80000		80200		78500	
Live " " " " "	258000		258000		280000		306000		306000		306000		306000		415000		415000		415000		415000	
Total " " " "	296200		296100		331600		362200		362000		362500		362600		493500		495000		495200		493500	
Section mondulus - nominal size	2740		2990		3410		3580		3410		3410		3890		4100		4270		4860		4320	
Bending stress - lbs./sq. in. - nominal size	1300		1190		1170		1220		1280		1280		1120		1450		1390		1220		1370	
Section mondulus - dressed size	2550		2800		3200		3360		3200		3200		3670		3840		4000		4600		4080	
Bending stress - lbs./sq. in. - dressed size	1400		1280		1240		1300		1360		1360		1190		1540		1490		1290		1450	
Longitudinal shear - Standard formula - First driver at quarter point.																						
Dead load = WL/2	16300		16200		17400		18300		18200		18400		18400		21900		22300		22400		22000	
Live load	76100		76100		77500		78800		78800		78800		78800		86600		86600		86600		86600	
Total load	92400		92300		94900		97100		97000		97200		97200		108500		108900		109000		108600	
Cross - Section - sq. in. - nominal size	1176		1120		[illegible]		1344		1280		1280		1296		1536		1600		1620		1440	
Unit shear - lbs./sq. in. = $\frac{3}{2}\frac{R}{A}$	118		124		111		108		114		114		112		106		102		101		113	
Cross - Section - sq. in. - dressed size	1134		1085		1240		1302		1240		1240		1260		1488		1550		1575		1400	
Unit shear - lbs./sq. in. = $\frac{3}{2}\frac{R}{A}$	122		128		115		112		117		117		116		109		105		104		116	
Longitudinal shear based on tests by Forest Products Laboratory. First driver at 3 x ht. of beam from support.																						
Dead load = $\frac{W(L-2h)}{2}$	13000		12400		13500		14300		14300		14400		13800		17900		[illegible]		17700		17400	
Live load	67600		61400		64800		68100		68100		68100		62300		65500		85500		73500		73500	
Total load	80600		73800		78300		82400		82400		82500		76100		103400		103700		91200		90900	
Cross - Section - sq. in. - nominal size	1176		1120		1280		1344		1280		1280		1296		1536		1600		1620		1440	
Unit shear - lbs./sq. in. = $\frac{3}{2}\frac{R}{A}$	103		99		92		93		97		97		88		101		97		85		95	
Cross - Section - sq. in. - dressed size	1134		1085		1240		1302		1240		1240		[illegible]		1488		1550		1575		1400	
Unit shear - lbs./sq. in. = $\frac{3}{2}\frac{R}{A}$	107		103		95		95		100		100		91		104		100		87		[illegible]	
Longitudinal shear based on tests by Forest Products Laboratory using revised shear formula. First driver at 3 x ht. of beam from support.																						
Dead load = $\frac{W(L-2h)}{2}$	13000		12400		13500		14300		14300		14400		13800		17900		18200		17700		17400	
Live load = $\frac{10}{9}\frac{P}{L}\frac{(L-X)\left[\frac{x}{h}\right]^2}{2+\left[\frac{x}{h}\right]^2}$	64500		58100		61500		64800		64800		64800		59100		77400		77400		70600		70600	
Total load -	77500		70500		75000		79100		79100		79200		72900		95300		95600		88300		88000	
Cross - Section - sq. in. - nominal size	1176		1120		1280		1344		1280		1280		1296		1536		1600		1620		1440	
Unit shear - lbs./sq. in. = $\frac{3}{2}\frac{R}{A}$	96		94		88		88		93		93		84		93		90		82		92	
Cross - Section - sq. in. - dressed size	1134		1085		1240		1302		1240		1240		1260		1488		1550		1575		1400	
Unit shear - lbs./sq. in. = $\frac{3}{2}\frac{R}{A}$	100		97		91		91		96		96		87		[illegible]		93		84		[illegible]	

ASSUMPTIONS:

L = Distance C. to C. bents for bearing on caps
= Distance face to face of caps + 6" for stringer bending and shear. (Assume 14" cap)
W = Total Dead Load per lin. ft. of track
Rail and fastenings = 200 #/lin. ft.
Ballast = 120 #/cu. ft.
Timber = 5 #/FBM

h = Height of Stringer in feet
P = Wt. on one driving axle = 72000 #
x = Distance of load from support in feet
Dressed size = Nominal size less 1/2" in depth.
In calculating bearing, bending, and shear stresses outer Stringers are considered as carrying no load.

complete data. The shear values in the table are calculated as discussed in last year's report (see page 835, Vol. 36, AREA Proceedings). In this connection, attention should be called to a misprint in the shear formula shown on the page referred to. The fraction $\frac{x}{h}$ in the numerator and denominator is to be squared and not merely the letter "X". The formula should read:

$$\Sigma \ \frac{10}{9} \ \frac{P}{L} \left[\frac{(L-X)\left[\frac{X}{h}\right]^2}{2+ \quad \left[\frac{x}{h}\right]^2} \right]$$

There is shown on the proposed ballasted deck design the same type of longitudinal bracing as was shown last year for the open deck trestle. The Committee would particularly like to have criticism of this bracing layout with the idea of working out a system which will more effectively utilize the timber.

Conclusion

1. It is recommended that the design of open deck trestle for E-72 loading submitted with this report, together with the table of stresses, be adopted for inclusion in the Manual as recommended practice.
2. It is recommended that the design for walks and platforms submitted with this report be adopted for inclusion in the Manual as recommended practice.
3. It is recommended that the plan and table of stresses for ballasted deck trestle for E-72 loading submitted with this report be accepted as information.

Appendix E

(5) BEARING POWER OF WOOD PILES, WITH RECOMMENDATION AS TO METHODS OF DETERMINATION

Wm. A. Oliver, Chairman, Sub-Committee; C. S. Johnson, W. N. Keeney, W. L. Peoples, G. W. Rear, W. R. Roof, W. J. Ryan.

The Sub-Committee this year has collaborated with other interested organizations and compiled a bibliography on the bearing power of piles, supplementing and bringing up to date the material on piles which appeared in the "Bibliography of Physical Properties and Bearing Value of Soils," compiled by Morris Schrero and published in the Proceedings of the American Society of Civil Engineers, August, 1931. The bibliography compiled by this Sub-Committee is not in final shape for publication this year. However, it has been prepared in mimeographed form and copies are available for interested persons.

Appendix F

(6) RECOMMENDED RELATIONSHIPS BETWEEN THE ENERGY OF HAMMER AND THE WEIGHT OR MASS OF PILE FOR PROPER DRIVING, TO INCLUDE CONCRETE PILES

W. R. Wilson, Chairman, Sub-Committee; R. W. Gustafson, R. P. Hart, W. N. Keeney, W. L. Peoples, H. T. Rights, W. J. Ryan.

Various agencies actively connected with driving piles were asked as to the method they used for determining the weight of hammer used in actual practice. The following is a summary of the answers received.

Navy Department, Bureau of Yards and Docks. (Concrete Piles). "Steam hammers for driving concrete piles shall have sufficient weight and power to develop an energy per blow, at each pull stroke, of not less than 3,500 foot-pounds per cubic yard of concrete of the pile being driven. The minimum weight of the entire hammer and of the striking part and the length of stroke should, where practicable, be specified for each project. Where hard driving is encountered, however, it may be necessary to reduce the length of stroke in order to avoid injurious stress to the piles."

Earl R. Evans, Vice Pres., McKiernan Terry Corp.

CONCRETE PILES

"Steam Hammers shall develop an energy per blow, at each piston stroke, of not less than 3,500 foot-pounds per cubic yard of concrete contained in the pile. The total energy developed by the hammer shall not be less than 12,000 foot-pounds per blow. Gravity hammers when used shall weigh not less than the pile and the maximum drop shall not exceed 8 feet . . . this specification is in general use in the Bureau of Public Roads as well as the majority of State Highway Departments throughout the United States, and has also been incorporated in a great many other specifications of other engineering bodies of other divisions of the government such as county and city, as well as on private projects."

TIMBER PILES

"We recommend the use of the Engineering News formula, which is the generally accepted formula amongst engineers, for determining safe bearing capacity of piles with a limiting factor that the final set in inches under the last few blows shall not be less than 0.1 of an inch. This of course refers to the double acting hammer. Furthermore, the hammer shall develop its energy in foot pounds at a velocity not to exceed that imparted to the ram at an equivalent free fall of not over 5½ feet. With these two limiting factors, namely, 0.1 of an inch minimum movement under the last few blows and the velocity of hammer not to exceed that of a free fall of 5½ feet, we believe constitutes a very conservative yet rational relationship between the size of hammer and timber pile."

Vulcan Iron Works:

"In determining the weight, or size, and capacity, of the hammer to be used for any service, due consideration must be given to the character of the soil, but another and very important factor is the ratio of the weight of the individual pile to the weight of ram that is to drive it. The blow should be struck by a ram not only possessing sufficient energy to overcome the inertia of the pile and the frictional and elastic resistances encountered, but also of sufficient weight to reduce to a minimum the portion of this energy which is unavoidably dissipated in destructive work during impact.

"The employment of a hammer having a ram weighing less than one-quarter of the pile is not recommended. Experience has shown that, everything considered, the most economical results are obtained with a hammer equipped with a ram weighing about the same as the pile. In regard to driving concrete piles, theoretical investigations concerning the local strength of these piles under a blow indicate that the proper weight, in pounds, of ram to provide should be equal to about 25 times the sectional area of the pile in square inches, regardless of the length of pile or striking energy required. The possibility of damage to the pile increases as the square root of the fall of ram; or in other words, directly as the velocity of impact."

Oregon State Highway Commission:

"Hammers for Concrete Piles. Concrete piles preferably shall be driven with steam hammers. Steam hammers for this purpose shall develop an energy per blow at each full stroke of the piston of not less than 3,500 foot-pounds per cubic yard of concrete in the pile being driven. The total energy developed by the hammer shall be not less than 6,000 pounds per blow. Care shall be exercised to see that the hammer is operating at its rated length of stroke and at the proper speed in strokes per minute. The ram shall not travel at a greater velocity than 18 feet per second, at the instant of impact.

"Gravity hammers, when used, shall weigh not less than the weight of the pile and the maximum drop shall not exceed eight feet."

From Oregon Highway Commission Standard Specifications:

"Hammers for Timber Piles. Gravity hammers for driving timber piles shall weigh not less than 2,500 pounds and the fall shall be so regulated as to avoid injury to the pile and shall in no case exceed 20 feet."

E. M. Philpot, Vice-President, Union Bridge & Construction Co., Kansas City:

"These matters are largely decided in each specific instance from the circumstances at hand, being governed by the general rule that for expeditious driving we use the heaviest hammer available that can be handled by the equipment in use and that our judgment indicates the pile will stand.

"Generally speaking, this rule has worked satisfactorily, although on a few occasions with wood piles we find that the breakage of piles has been excessive on account of too heavy hammer. On the other hand, we have on several occasions been surprised in observing some of our neighbors get piles down to a satisfactory penetration with small hammers that we would not have considered using had we been planning the work."

Frank M. Cortelyou, Harrington & Cortelyou, Kansas City:

"It is our custom to make borings for determining the materials through which piles are to be driven, even though our general knowledge of conditions is such as to show that piles will be necessary. We believe that this is almost essential, not only for a determination of the probable penetration required, but also for a proper interpretation of the behavior of the piles while being driven. In certain cases such information is also necessary for a preliminary judgment as to the type of equipment most suitable for driving.

"For driving test piles we prefer to use a drop hammer, in place of a steam hammer and, likewise, prefer a single acting steam hammer over a double acting hammer. We likewise prefer a heavy drop hammer weighing around 4,000 pounds to one weighing from 2,800 pounds to 3,200 pounds, as we believe less injury is done to the pile with the lower velocity of the hammer at the point of striking the pile. For concrete piles, especially when they are to be driven without jetting, we prefer to use a steam hammer with a preference for those with the heavier striking parts."

A series of steel H sections for use as piling is now being rolled by the Illinois and Carnegie Steel Companies and the Bethlehem Steel Corporation. Pamphlets published by the above concerns contain the results of tests of various sizes of steel H sections used as piles under various conditions.

The Committee invites attention to the following:

Pile Driving Calculations with notes on Driving Forces and Ground Resistance, by A. Hilley, Structural Engineer, Vol. VIII, July–Aug. 1930.

Reinforced Concrete Pile Formulae, by David Victor Isaacs, Vol. XII, Transactions Australian Institute of Civil Engineers.

Report of the British Building Research Board 1932.

Article by A. Hilley, "Engineering", Vol. 113, pages 673–4, 711–14, and 745–6.

W. N. Keeney, Bridge Engineer, American Wood Preservers' Association, a member of this Committee, has prepared a study of the various theoretical formulae for Bearing Power of Wood Piles and a theoretical method of determining the Best Relationships between the Energy of Hammer and the Weight or Mass of Pile for Proper Pile Driving, which appears as Exhibit A.

It is the recommendation that this report be received as information.

Exhibit A

BEARING POWER OF WOOD PILES

There are two methods of determining the load-bearing value of piles: (a) by test; (b) by use of formulae based on the behavior of the pile driven by a hammer of known energy. While the first method is the only one satisfactory for determining in all cases the loads which a pile will safely carry, the second, because of the expense or impracticability of making tests for all structures, will continue to be used in determining the bearing capacity in many if not the majority of cases. It is therefore important that the formula be as reliable as possible.

Any discussion of pile bearing capacities naturally brings up the comparison of formulae, particularly those, tested by actual experience and in more or less common use. Any formula used must be simple, must not involve an unnecessary amount of variables, and should at the same time take into consideration calculable losses of efficiency in driving which can be evaluated with a considerable degree of certainty.

It is generally recognized that a considerable part of the theoretical energy of the hammer blow is dissipated in unprofitable work such as, for example, the loss of energy due to impact, loss due to the elasticity of the pile itself, and loss arising from imperfectly centered blows, etc. In some formulae an attempt has been made to compensate for these losses by an additive factor in the denominator of the basic equation $\frac{wh}{s}$. In a few other formulae—notably, that of the Bureau of Yards and Docks, and the Eytelwein formula, factors are introduced which more nearly compensate for the decrease in the hammer energy which actually occurs.

The most important loss is probably that due to the impact of the hammer on the pile head, or driving cushion, and this loss is calculable. A. Hilley, in England, made some very comprehensive and thorough tests to determine the relative importance of the several component parts of energy expended in pile driving. The report of this test is to be found in "Engineering," Vol. 113, pages 673–4, 711–14, 745–6. For calculating the efficiency of the hammer blow he gives the formula.

$$\frac{1}{1+\frac{p}{w}}+\frac{\lambda^2}{1+\frac{w}{p}}$$

which is placed in very convenient form for computing the energy of the blow actually delivered to the pile head. $\frac{p}{w}$ represents the ratio of pile weight to the weight of the kinetic member of the hammer and λ is the coefficient of restitution. To the actual weight of the pile should of course be added the weight of the cap and other static parts, which increases the inertia. The values of λ commonly met with in driving piling are:

For iron on hardwood	0.25
For iron on concrete	0.4

So that the loss of energy which occurs when the hammer strikes the pile may be readily ascertained, a curve has been plotted (Fig. 1) using the above formula with λ taken at 0.25. This value of λ can usually be taken, as a hardwood cap is interposed between the pile and the ram in driving piling other than wood, and the loss is little affected whether the wood be short blocks such as are used in the cap, or the full length of the wood pile. Fig. 1 is a plot of this formula giving the percentage of efficiency of the various ratios of $\frac{p}{w}$ and shows the rapid decrease in efficiency which occurs as the ratio $\frac{p}{w}$ increases in value up to ratios not uncommon in pile driving practice today. While the loss of efficiency is considerably more important in the heavier types of piling, there is nevertheless a considerable decrease in efficiency with heavier wood piles, the weight of which added to that of the driving cap often amounts to considerable in comparison with the weight of the kinetic member of the hammer. It is believed that this loss of efficiency should be taken into account in determining the capacity of all classes of piling.

Sometime ago the Bureau of Yards and Docks at San Diego made a very exhaustive test, where a concrete pile was driven and loaded so as to develop empirically a curve of bearing values against the penetration per blow. Against this test curve were plotted numerous formulae which had from time to time been in use for determining the bearing value of piles. The test is reported in "Bulletin No. 36—Public Works of the Navy" on page 74. Fig. 2 is taken from the plate accompanying the description of this test in Bulletin No. 36 and reproduces the more commonly used curves for steam hammers shown on the plate. The formulae plotted on Fig. 2 are:

(1) Engineering News .... $L=\frac{2wH}{s+0.1}$

(2) " " .... $L=\frac{2wH}{s+0.3}$

(3) Bureau of Yards and Docks .... $L=\frac{2wH}{s(1+0.3\frac{p}{w})}$

(4) " " " " " .... $L=\frac{2wH}{s\frac{p}{w}+0.1}$

(5) Eytelwein .... $L=\frac{2wH}{s(1+\frac{p}{w})}$

Where $L=$ safe load in pounds,
$H=$ drop in feet,
$w=$ weight of hammer in pounds,
$p=$ weight of pile in pounds, and
$s=$ average penetration, in inches, from last blows.

Removing the factor of safety of 6, the formulae may be written, to give ultimate loads, as follows:

(1) Engineering News .... $\frac{wh}{s+0.1}$ (h and s in inches)

(2) " " .... $\frac{wh}{s+0.3}$ " " " " "

(3) Bureau of Yards and Docks .... $\frac{wh}{s+0.3\frac{p}{w}}$ " " " " "

(4) " " " " " .... $\frac{wh}{s\frac{p}{w}+0.1}$ " " " " "

(5) Eytelwein .... $\frac{w}{w+p}\cdot\frac{wh}{s}$ " " " " "

While the formulae given are in practice usually used with the factor of safety of 6, they are above cited in a form which gives ultimate loads and are plotted on the basis of ultimate loads for comparison.

On Fig. 3 are plotted the pile tests reported on page 71 of Bulletin 349 of the American Railway Engineering Association dated September, 1932. The actual test loadings secured are plotted against the Engineering News formula, the formula of the Bureau of Yards and Docks, and the Eytelwein formula. Both Curves 3 and 4 are the Eytelwein formula. There are, however, as shown on the plot, different hammer weights and different ratios for $\frac{w}{w+p}$. On this figure in addition has been sketched the curve $\frac{ewh}{s}$ in which e is the efficiency of the blow determined from Fig. 1.

It will be noticed in Fig. 2 that of the five formulae plotted, the Eytelwein lies nearest the actual test curve—Curve 6, and agrees fairly closely with the results obtained by actual test.

In Fig. 3 it will be noticed that the Eytelwein formula lies reasonably close, for all piles, to the results obtained in the actual test when the corresponding value of $\frac{w}{w+p}$ is used.

If the formula for the efficiency of the hammer blow given above, namely

$$\frac{1}{1+\frac{p}{w}} + \frac{\lambda^2}{1+\frac{w}{p}},$$

is multiplied into the basic formula $\frac{wh}{s}$, there results

$$\frac{wh}{s}\left(\frac{1}{1+\frac{p}{w}} + \frac{\lambda^2}{1+\frac{p}{w}}\right)$$

Since λ^2 is a very small quantity, the second term in the parenthesis could be omitted. In ordinary cases of pile driving this additional capacity secured by considering this second term would not be appreciable. Its neglect is on the side of safety and tends to compensate for some of the more or less indeterminate losses which result in addition to the main loss of efficiency from the hammer blow. Neglecting the second term, the equation may therefore be written

$$\frac{wh}{s(1+\frac{p}{w})}$$

When h is changed to feet and the safety factor of 6 is introduced, this becomes

$$\frac{2wH}{s(1+\frac{p}{w})},$$

which is exactly the Eytelwein formula.

It therefore seems that this formula takes into account the calculable losses which actually occur and is more nearly in accord with results than the other formulae considered. It has been quite widely used by the Bureau of Yards and Docks. Captain Geo. A. McKay, in "Notes on Pile Foundations" in "Bulletin No. 33, Public Works of the Navy," in discussing some of the formulae proposed for the determination of pile capacities, states:

> "A form which has been suggested for consideration is
>
> $$L = \frac{2\,Wh}{S\frac{w}{W} + .1}$$
>
> Comparison of this suggested form, however, with the Eytelwein formula,
>
> $$L = \frac{2Wh}{S(1+\frac{w}{W})}$$
>
> has shown that the latter gives more logical results, and the bureau in its latest specifications has used the Eytelwein form and will continue to do so until something better is found."

Best Relationships Between the Energy of Hammer and the Weight or Mass of Pile for Proper Pile Driving

As an approach to the problem of the proper selection of hammer weights to weight of pile, Fig. 1 and 1A are submitted.

Fig. 1, as already explained, represents the efficiency of the blow delivered to the pile head beneath the cushion which is dependent upon the inertia of the pile. The full line curve is plotted using the coefficient of restitution $\lambda = 0.25$. This can generally be taken in practice as cited above, because if the hammer does not strike directly on a wood pile, a hardwood block or driving cushion is usually interposed, and the loss of energy is not appreciably affected whether a short block is considered or the full length of a wooden pile. The dotted curve is plotted with a value of $\lambda = 0.4$, which would be the case if the iron hammer struck directly on the concrete pile head unprotected.

Fig. 1A. The capacity of a driven pile is given by the equation $\frac{eWh}{s} = L$

e = Proportion of hammer energy converted into useful work
Wh = Hammer energy in inch pounds
s = Penetration per blow in inches
L = Load in pounds

For the purpose of plotting Fig. 1A this equation is transposed to $e = \frac{Ls}{Wh}$. Ultimate capacities and hammer energies have been assumed and the required efficiency calculated for the different penetrations in inches shown. Driving limits of 0.25 and 0.75 inch penetration per blow have been plotted on the figure. It is assumed that where the piling is required to support heavy loads, driving will not stop under ordinary conditions while penetrations per blow are greater than 0.75 inch, and in general driving will not be continued after penetrations have decreased to less than 0.25 inch.

Suppose that a pile is to be driven to a 200,000-lb. capacity with a hammer of 15,000 foot-pounds or 180,000 inch-pounds of energy. Let it be assumed that the piling will be driven to a penetration of 0.4 inch per blow. Fig. 4 shows that a hammer efficiency of 47 per cent is required. Let it be assumed that the pile weighs 6000 pounds. The ratio of pile weight to hammer energy is therefore for this type of hammer 6000 ÷ 5000, or 1.2. Referring to Fig. 1, this ratio of P to W shows an efficiency of 49 per cent. It therefore seems that the hammer is satisfactory. Should a greater ratio of pile weight to weight of hammer exist, the desired capacity could still be developed if driving were continued until the penetration per blow were less than 0.4 inch. The figure, however, indicates the limits of each weight of hammer and is an aid to judgment in selecting the proper weight of hammer.

In the Spring of 1933, prior to the annual meeting, a paper on "Best Relationship between the Energy of Hammer and the Weight or Mass of Pile for Proper Pile Driving, to include Concrete Piles"*, by J. F. Seiler, was submitted as information on this subject. In this paper an equation was proposed and a curve plotted for determining the best relationship between hammer energy and weight of pile to develop ultimate capacities of 100,000 and 200,000 lb., respectively. The curve proposed was represented by the equation

$$R = H_{\circ} \frac{M^2P + C_1^2}{C_{\circ} C_1 P} \qquad \text{(1)}$$

Where $H_{\circ}$ = Hammer energy required to develop capacity $C_{\circ}$ in any pile weighing 5000 lb. or less

$$\left.\begin{aligned} M &= \text{Mass of pile} \\ P &= \text{Weight of pile} \\ C_1 &= \text{Capacity to be developed} \end{aligned}\right\} \text{Pounds}$$

NOTE.—$H_{\circ}$ assumed = 12,000 foot-pounds for $C_{\circ}$ = 100,000 lb.

NOTE.—Ultimate capacities $C_{\circ}$, C_1, etc., are assumed to be double actual design load.

Fig. 4 was plotted to check the proposed curves of Equation 1 against formulae for capacities showing close agreement with test loadings.

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* See page 761, et seq., Vol. 34, Proceedings of the American Railway Engineering Association.

On Fig. 4 Curves A and B are plotted to show the ratios of hammer energy to weight of pile for hammer energies of 15,000 foot pounds (180,000 inch pounds) and 24,000 foot-pounds (288,000 inch pounds), respectively. From Equation 1 above, by making proper substitutions in the formula, curves representing capacities of 100,000, 150,000, and 200,000 lb., can be sketched. These capacity curves enable the superimposing of Curves C and E on Curve A, and Curves D and F on B for comparison. C and D are graphs of the Eytelwein formula $\frac{W}{W+P} \cdot \frac{Wh}{3s}$, while E and F are graphs of the basic formula $\frac{eWh}{3s}$ (e being taken from curve of Fig. 1), capacities for both being calculated for a penetration of 0.25 inch per blow. The factor 3 has been introduced in the denominator because Equation 1 was proposed for a factor of safety of 2, i.e., the capacity curves submitted in the original paper were assumed to be twice the design loads, while the formulae of the superimposed curves without the factor of 3 are for ultimate loads of six times the design load. The introduction of the factor 3 in the denominator of the two latter, therefore, makes the three equations comparable.

The close agreement of the three curves in each group shows a reasonably close check with Equation 1 and indicates the value of the graph plotted from that equation as a guide to selecting hammer energies suitable for proper driving of the different weights of piling.

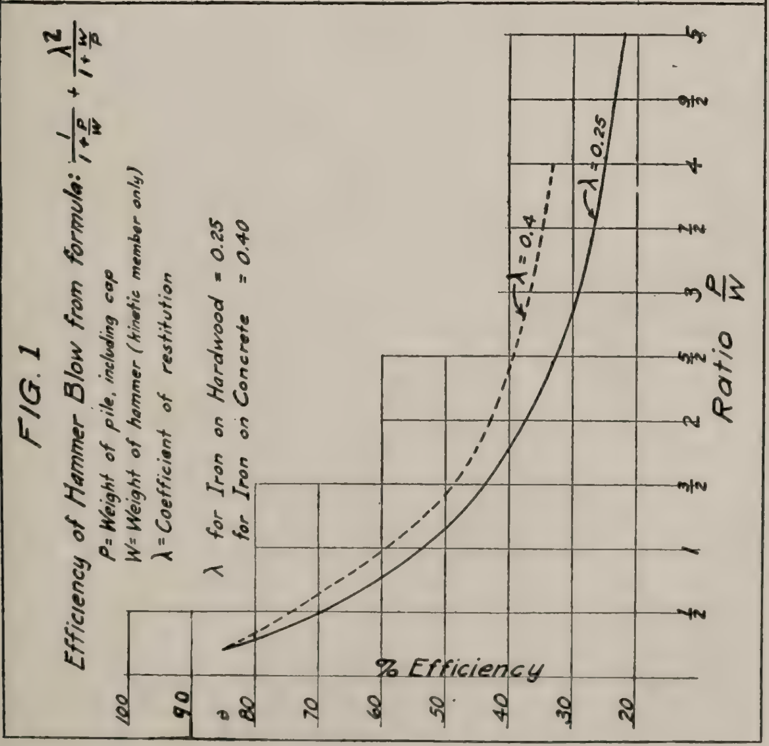


FIG. 1

Efficiency of Hammer Blow from formula: $\frac{1}{1+\frac{P}{W}} + \frac{\lambda^2}{1+\frac{W}{P}}$

P = Weight of pile, including cap

W = Weight of hammer (kinetic member only)

λ = Coefficient of restitution

λ for Iron on Hardwood = 0.25

for Iron on Concrete = 0.40

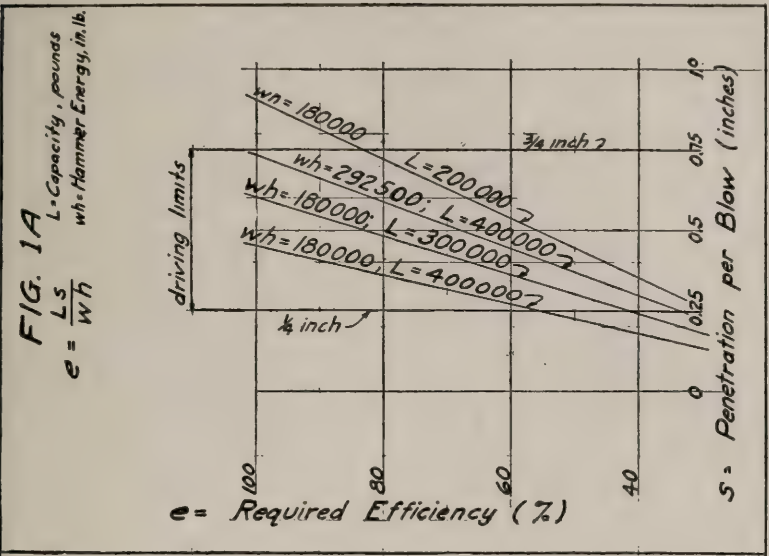


FIG. 1A

$e = \frac{Ls}{wh}$

L = Capacity, pounds

wh = Hammer Energy, in. lb.

FIG. 2

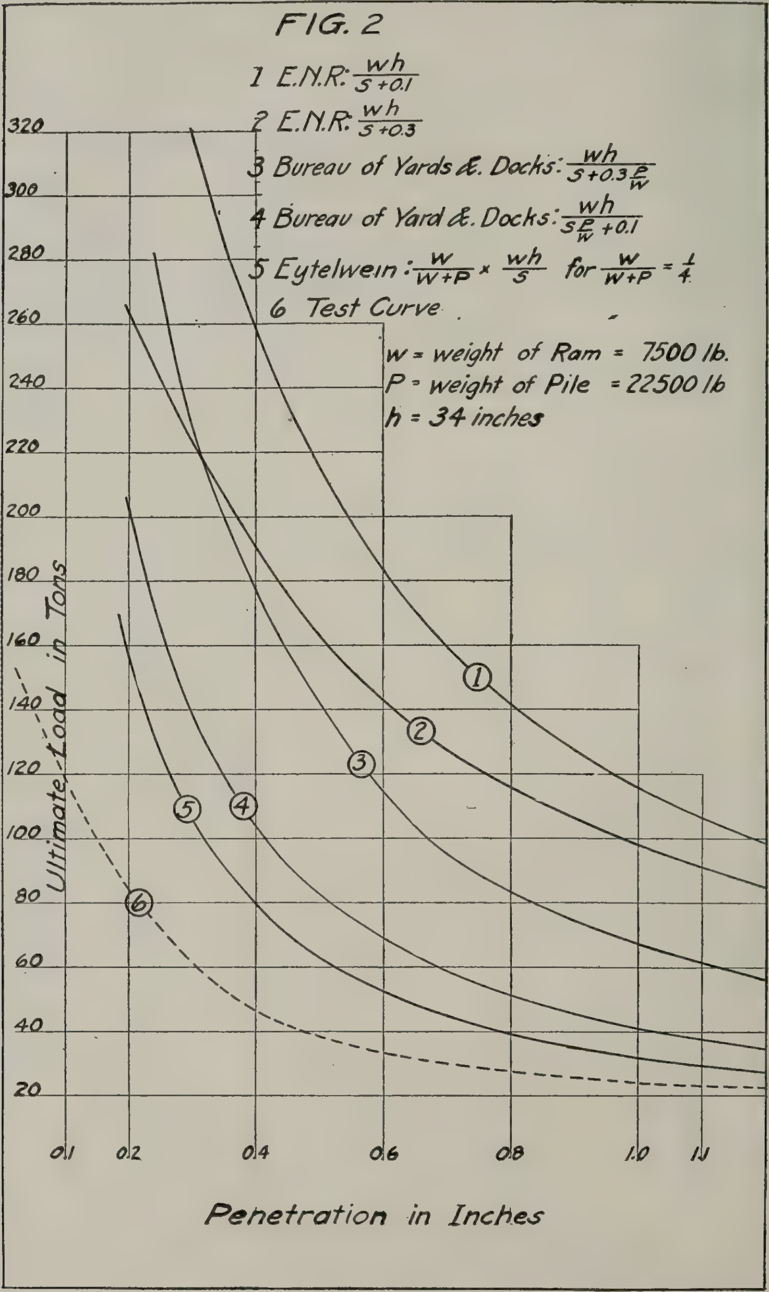

1 E.N.R.: $\frac{wh}{S+0.1}$
2 E.N.R.: $\frac{wh}{S+0.3}$
3 Bureau of Yards & Docks: $\frac{wh}{S+0.3\frac{P}{W}}$
4 Bureau of Yard & Docks: $\frac{wh}{S\frac{P}{W}+0.1}$
5 Eytelwein: $\frac{W}{W+P} \times \frac{wh}{S}$ for $\frac{W}{W+P} = \frac{1}{4}$
6 Test Curve
w = weight of Ram = 7500 lb.
P = weight of Pile = 22500 lb
h = 34 inches
①
②
③
④
⑤
⑥
Ultimate Load in Tons
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0.1
0.2
0.4
0.6
0.8
1.0
1.1
Penetration in Inches

FIG. 3

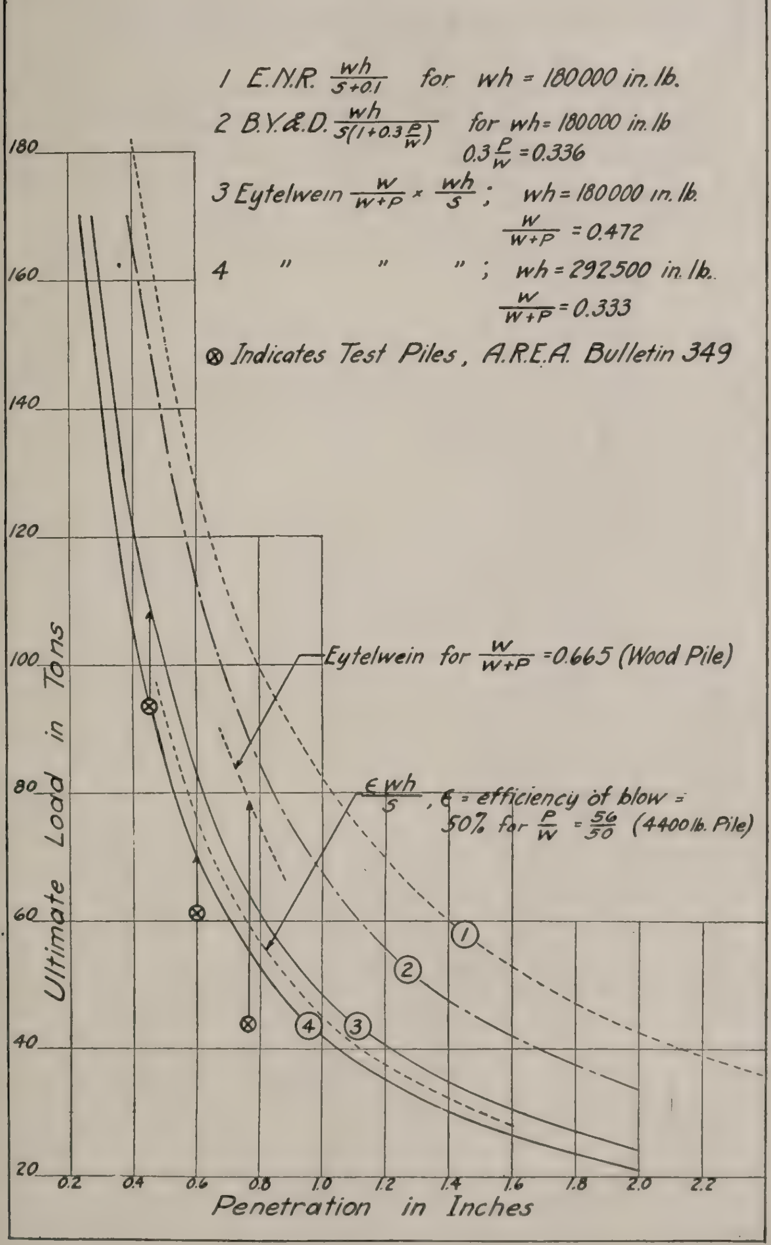
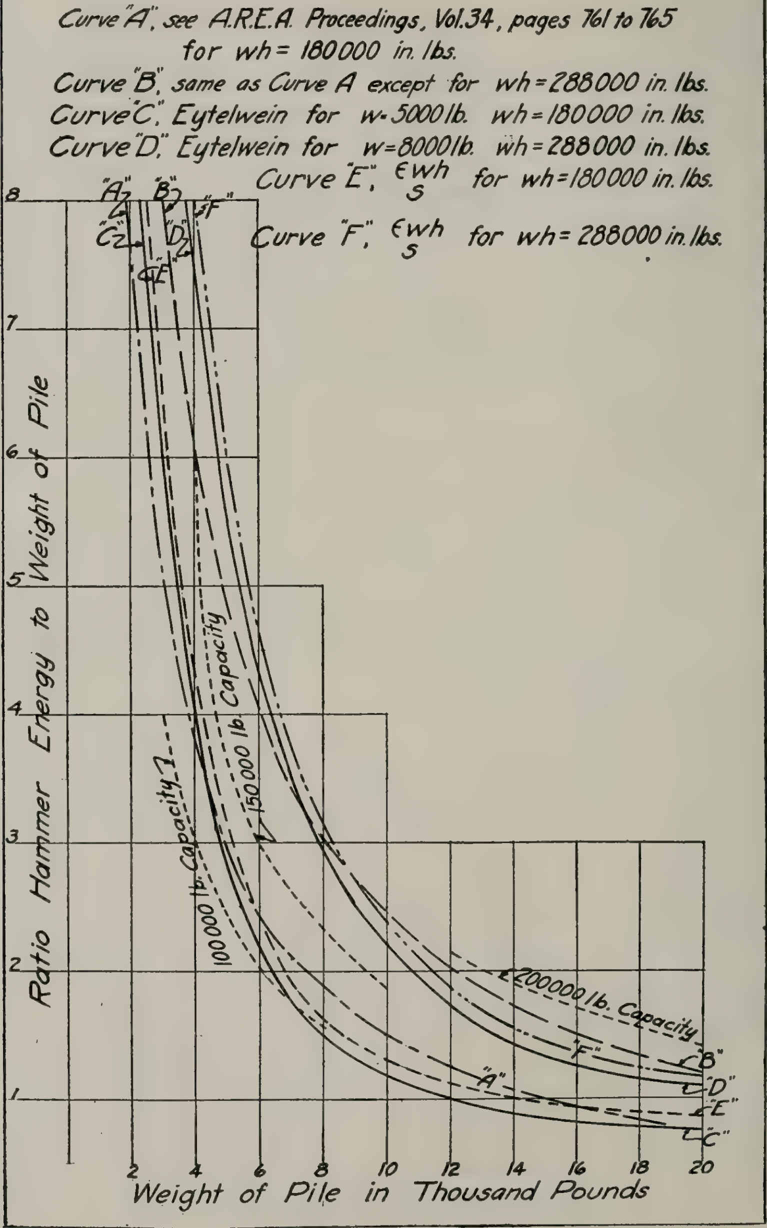

1 E.N.R. $\frac{wh}{s+0.1}$ for wh = 180000 in. lb.
2 B.Y.&.D. $\frac{wh}{s(1+0.3\frac{P}{W})}$ for wh = 180000 in. lb
$0.3\frac{P}{W} = 0.336$
3 Eytelwein $\frac{W}{W+P} \times \frac{wh}{s}$; wh = 180000 in. lb.
$\frac{W}{W+P} = 0.472$
4 " " " ; wh = 292500 in. lb.
$\frac{W}{W+P} = 0.333$
⊗ Indicates Test Piles, A.R.E.A. Bulletin 349
Eytelwein for $\frac{W}{W+P}$ = 0.665 (Wood Pile)
$\frac{\epsilon wh}{s}$, ϵ = efficiency of blow = 50% for $\frac{P}{W} = \frac{56}{50}$ (4400 lb. Pile)
①
②
③
④
Ultimate Load in Tons
180
160
140
120
100
80
60
40
20
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
Penetration in Inches

FIG. 4


Curve "A", see A.R.E.A. Proceedings, Vol. 34, pages 761 to 765
for wh = 180000 in. lbs.
Curve "B", same as Curve A except for wh = 288000 in. lbs.
Curve "C", Eytelwein for w-5000 lb. wh = 180000 in. lbs.
Curve "D", Eytelwein for w = 8000 lb. wh = 288000 in. lbs.
Curve "E", ϵwh/s for wh = 180000 in. lbs.
Curve "F", ϵwh/s for wh = 288000 in. lbs.
"A"
"B"
"C"
"D"
"E"
"F"
100000 lb. Capacity
150000 lb. Capacity
200000 lb. Capacity
Ratio Hammer Energy to Weight of Pile
Weight of Pile in Thousand Pounds
1
2
3
4
5
6
7
8
2
4
6
8
10
12
14
16
18
20

APPENDIX G

(8) DESIGN OF AND SPECIFICATIONS FOR WASHERS, SEPARATORS, CAP-STRINGER STRAPS AND OTHER WOOD BRIDGE AND TRESTLE FASTENINGS

G. M. Cornell, Chairman, Sub-Committee; S. F. Grear, R. W. Gustafson, R. P. Hart, C. S. Johnson, H. T. Rights, W. R. Roof.

In the study of this subject this year investigation was made of the design used on various railways for the following items:

1. O. G. washers
2. Separators
3. Boat spikes
4. Guard rail lag screws
5. Drift bolts
6. Timber construction bolts

The general practice in connection with Item 1 is for each company to have its own design of washer although a few roads buy according to commercial standard. As between various railroads there are slight differences in design but all designs investigated satisfied the dimensions called for under Cast Washers or Wrought Washers on page 468 of the 1929 Manual with the exception that in at least two cases of malleable washer the size of hole was only 1/16 inch larger than the bolt diameter instead of ⅛ inch larger as called for in the Manual. No reason has been presented for changing the design requirements as shown in the Manual and it is believed that any savings that might result from complete standardization of cast or malleable washer design are negligible. Specifications for both cast and wrought iron are now included in the Manual.

Item 2, separators, are in much the same category as O. G. washers. Most of the railroads whose practices were investigated have their own designs for separators. However, the simplest and most practical method of making a separator appears to be to use two O. G. washers back to back. This eliminates entirely the necessity for carrying in stock any separators and the practice is recommended. It is not believed that any special design of separator is warranted. Specifications for materials used in washers are now contained in the Manual.

Boat spikes and lag screws are almost universally ordered to commercial standard and no change is recommended in this practice. A few tests of special appliances, such as the Lewistite screw for guard rails, are under way but data are not at hand to warrant any conclusions as to the advantages of these fastenings.

Drift bolt and timber construction bolts are either made up from scrap stock by the railroads or are purchased on the market to commercial standards. The 1929 Manual contains specifications which cover the material used in these fastenings and investigation develops no particular incentive for setting up of standard plans to cover them.

There is one point in connection with the design of bolts which should receive more serious consideration than has apparently been given in the past and that is the question of diameter. This matter is of particular importance in connection with the lateral and longitudinal bracing system and some study of the problem has been made to determine whether changes should be recommended in present designs.

In Technical Bulletin No. 332, United States Department Agriculture, "The Bearing Strength of Woods Under Bolts", a method of determining safe loads for bolts is presented which is based on test data developed at the Forest Products Laboratory. The longitudinal and sway bracing of the standard timber trestles is fastened to 12 inch or

14 inch posts or piles by bolts and boat spikes. The sway braces have one ¾ inch bolt and two ⅜ in. × 8 in. boat spikes. The longitudinal bracing is fastened to the posts or piles with two ⅞ inch bolts and one boat spike. Assuming that the bolts are under one end loading and that the posts are 12 inch thick the bearing values of various size bolts, calculated in accordance with recommendations in Technical Bulletin No. 332, are as follows:

Bearing parallel to the grain:

¾″ diam. bolt—Design load 885 lb.—Ultimate load 1990 lb.
⅞″ " " — " " 1205 lb.— " " 2710 lb.
1″ " " — " " 1570 lb.— " " 3530 lb.

Bearing perpendicular to the grain:

¾″ diam. bolt—Design load 480 lb.—Ultimate load 1080 lb.
⅞″ " " — " " 600 lb.— " " 1350 lb.
1″ " " — " " 815 lb.— " " 1830 lb.

Bearing at an angle of 45 deg. to the grain:

¾″ diam. bolt—Design load 640 lb.—Ultimate load 1440 lb.
⅞″ " " — " " 800 lb.— " " 1800 lb.
1″ " " — " " 1090 lb.— " " 2450 lb.

The slip of the joint at design load will probably be about 0.02 to 0.04 inch and at ultimate load about 0.10 inch.

Under present practice the bracing of timber trestles, with the exception of the longitudinal struts, is made up of 3″ × 10″ timbers. The weakest bracing members are the longitudinal cross braces which, in a fifteen foot span, may have a length of 20.5 ft. If it is assumed that these members are loaded in compression with no support between ends the allowable design load on one brace is 1950 lbs., the modulus of elasticity being 1,600,000 lb. per sq. in. From this minimum value the allowable design load may run up to 32,400 lb. for a member in tension with 1,200 lb. per sq. in. unit design stress on a net section of 27 sq. in. Under an assumption of a factor of safety of 3 the ultimate loads would range from 5,850 lb. to 97,200 lb. The longitudinal cross braces frame into the posts or piles at an angle of about 45 deg. and thus the value of two ⅞ in. diameter bolts is 1,600 lb. or 82 per cent of the minimum load value of the brace. The ultimate strength of the connection is only 3,600 lb. or 185 per cent of the safe working load on the brace. If, as seems quite reasonable, the brace is considered as supported at its midpoint the value of the brace in compression is 7,800 lb. working load. The two ⅞ in. diameter bolts are good for only 20.5 per cent of this load under working stress or 46.0 per cent under ultimate stress. The value in compression of the 6″ × 10″ longitudinal strut in a 15 ft. span is 29,160 lb. or 24.3 times the 1,200 lb. value of the two ⅞ in. diameter bolts fastening it. (These bolts bear against the post perpendicular to the grain and hence have a value of only 600 lb. per bolt.)

During the past few years development work has been done on the design and use of timber connectors for joints. In the bulletin "Modern Connectors for Timber Construction" issued in 1933 by the National Committee on Wood Utilization, U. S. Department of Commerce, and the Forest Products Laboratory, U. S. Department of Agriculture, several designs are considered and recommended working loads as developed by test data are presented. In Fig. 1 to Fig. 5 are shown what probably would be the most useful types of connectors in the bracing system of timber trestles. Recommended safe working loads for particular sizes of these various types of connectors are as follows:

		Recommended Safe Working Loads—Lb.		
Connector	*Bolt Diam.*	*Parallel to Grain*	*Perpendicular to Grain*	*At 45 Deg. to Grain*
5″ Sq. Bulldog	1″	4100	3075	(A) 3280
3¾″ Diam. Round Bulldog	¾″	2450	2205	(B) 2320
* 3″ × 5″ Oval Bulldog	1″	3375	(C) 3040	(B) 3200
5½″ Diam. Toothed Ring	⅞″	4200	3150	3150
** 4″ Diam. Split Ring	¾″	7000	4900	6000

Note (A).—Use 80 per cent of value parallel to grain.
Note (B).—Use 95 per cent of value parallel to grain.
Note (C).—Use 90 per cent of value parallel to grain.

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* Note.—Although the bulletin "Modern Connectors for Timber Construction" does not give any working load for the 3″ x 5″ oval connector as investigated by the Forest Products Laboratory it does give a value of 2.0 metric tons or 4400 lb. for this connector as used in European practice. European practice generally allows somewhat higher loads than American practice and it is estimated that a safe design load for the 3″ x 5″ oval Bulldog under the latter condition would be 3,375 lb. with a 1″ diam. bolt in bearing parallel with the grain.

** Note.—These values are the recommendations of the Timber Engineering Co., Washington, D. C., for dense grades of southern pine, Douglas fir, and similar woods.

In considering the use of the various types of connectors thought must be given to the ease of application and the relative effectiveness of each variety. In applying the devices the Bulldog and Toothed Ring types are put on the bolt between the two pieces of timber to be fastened. When the bolt is drawn up tight the teeth on the connectors are forced into the wood faces thereby establishing the grip on the timber. No extra framing of the timber is required although a special wrench is used to secure the necessary torque on the nut to pull the timbers together. The split ring connector requires that a special groove, concentric with the bolt hole, be cut in the face of both timbers. The ring is then set in this groove and forced into a tight fit when the bolts are drawn up. Thus from the standpoint of ease of application the split ring does not seem quite as desirable as the other types considered.

From a consideration of the relative effectiveness of the connectors the most desirable type for general use in the bracing system of timber trestles would appear to be the 3″ × 5″ oval Bulldog. In the case of framed structures where the braces fit against flat sided posts any of the connectors could be used equally well but in a pile structure where the flat brace is placed against a round pile the oval Bulldog has an advantage in that its long axis can be placed parallel with the axis of the pile thereby putting a greater area of the connector in effective contact with the pile. It is believed that for the purpose of fastening a brace to a pile the oval Bulldog will show the greatest load values.

Of the connectors considered above only the square Bulldog, the toothed ring, and the split ring are at present manufactured in this country. The square Bulldog has been used quite successfully as a tie spacer between guard rail and tie to eliminate the use of lag screws, the guard rail being fastened to every third or fourth tie by a bolt. The split ring has been used in a number of framed structures such as radio towers and roof trusses. Although the round and oval Bulldog types are not at present manufactured there is no question but that if the demand develops production will be forthcoming and experiments with them, particularly with the oval Bulldog, are recommended to determine their fitness for use in timber trestles.

Using the oval Bulldog connector for purposes of comparison the data discussed above may be summarized as follows:

Size of Brace	*Length*	*Value in compression*	*Value of 1 bolt 1″ diam.*	*Value of 3″ × 5″ Bulldog*
3″ × 10″	20.5 ′	1950#	1090#	3200#
3″ × 10″	10.25′	7800#	1090#	3200#
3″ × 10″	0.0 ′	36000#	1090#	3200#
6″ × 10″	15.0 ′	29160#	1090#	3200#

From this table it is apparent that, though the use of two Bulldog connectors with 1″ diameter bolts will not completely develop the timber except in the case of the longitudinal cross bracing, the use of the connector will treble the value of the connection.

Where a connector is not used the calculations indicate that at least two 1 in. diameter bolts should be used at each point where a brace is fastened to a post. This design will ordinarily not nearly develop the strength of the brace but it will raise the strength secured by the present design of joint.

Recommendations

1. That the present specifications in the Manual covering the design and specification of cast or malleable washers and/or separators be continued and that no changes or additions thereto be made at the present time.
2. That boat spikes, lag screws, drift bolts, and construction bolts, when they are not made by the railway company, be purchased to manufacturers' standard.
3. That the use of modern connectors, especially the 3″ × 5″ oval connector, be given thorough trial in the bracing system joints with the idea of developing commercial production of a suitable type of connector.
4. That at all points where lateral or longitudinal bracing is fastened to posts or piles not less than two bolts each 1 inch in diameter be specified.

Appendix H

(9) REVIEW SPECIFICATIONS FOR OVERHEAD HIGHWAY BRIDGES OF THE ASSOCIATION OF STATE HIGHWAY OFFICIALS INSOFAR AS THEY RELATE TO WOOD CONSTRUCTION

S. F. Grear, Chairman, Sub-Committee; W. E. Hawley, C. J. Hogue, A. T. Upson.

The Committee has kept in touch with the Association of State Highway Officials and on account of the revision and reprinting of their Specifications for Highway Bridges finds it is not possible to make a final report at this time.

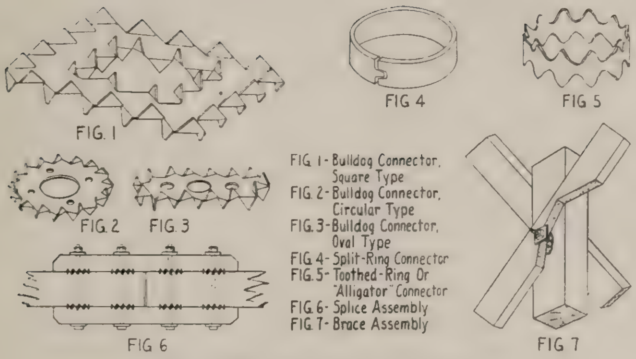


FIG. 1 FIG 4 FIG 5 FIG. 2 FIG. 3 FIG 6 FIG 7

FIG. 1 - Bulldog Connector, Square Type
FIG. 2 - Bulldog Connector, Circular Type
FIG. 3 - Bulldog Connector, Oval Type
FIG. 4 - Split-Ring Connector
FIG. 5 - Toothed-Ring Or "Alligator" Connector
FIG. 6 - Splice Assembly
FIG. 7 - Brace Assembly

WOOD CONNECTORS AND ASSEMBLIES

REPORT OF COMMITTEE XII—RULES AND ORGANIZATION

E. H. Barnhart, *Chairman;*
M. M. Backus,
W. C. Barrett,
D. P. Beach,
L. D. Beatty,
Richard Brooke,
H. L. Browne,
P. D. Coons,
W. O. Cudworth,
E. B. Crane,
J. L. Downs,
A. B. Griggs,
G. H. Harris,
H. C. Hayes,
E. G. Hewson,
A. A. Jackson,
B. R. Kulp,
R. E. Warden, *Vice-Chairman;*
H. A. March,
F. R. Puder,
W. A. Radspinner,
W. B. Stimson,
W. H. Vance,
F. B. Wiegand,
Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of the Manual (Appendix A).

(2) Rules for Guidance of Employees of the Maintenance of Way Department as applied to:

(a) Maintenance of Terminal Structures Other than Buildings, collaborating with Committees XIV—Yards and Terminals and XXIII—Shops and Locomotive Terminals. Progress in study—no report.

(b) Protection of Treated Ties and Timber, collaborating with Committees III—Ties, VII—Wood Bridges and Trestles and XVII—Wood Preservation. Progress.

(3) Rules for Fire Protection, collaborating with Committee XXII—Water Service, Fire Protection and Sanitation (Appendix B). Progress report.

The Committee on Rules and Organization,
E. H. Barnhart, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

P. D. Coons, Chairman, Sub-Committee; M. M. Backus, L. D. Beatty, H. L. Browne, J. L. Downs, R. E. Warden.

Present	*Proposed*
Table of Contents, pp. 792–795.	Eliminate.
General Notice, p. 795.	Eliminate, and substitute "See Standard Code, AAR."
General Rules, pp. 796–798; Rules 1–32 inclusive.	Insert after "General Rules": "See also Standard Code, AAR." Eliminate Rules 1, 3, 5, 6. Rule 2, eliminate first two sentences. Renumber Rule 1. Rule 14, eliminate and substitute: "Employees must be familiar with the rules and regulations in the current timetable." Renumber Rule 10. Renumber Rules 4 to 13 inclusive; 2 to 9 inclusive; 15 to 32 inclusive; 11 to 28 inclusive.

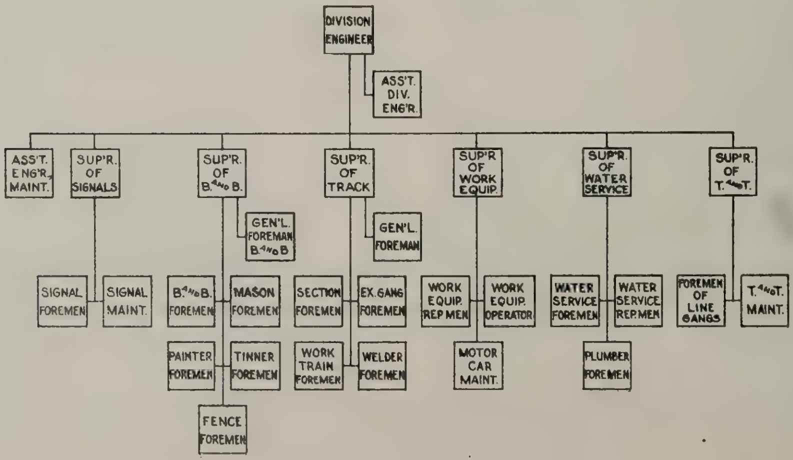
Bulletin 384, February, 1936.

Present	*Proposed*
Operating Rules, pp. 798–802. Rules 100–122 inclusive.	Eliminate all subject-matter under title. Insert after title "See also Standard Code, AAR." "100. When an employee does not have access to a standard clock, he must compare his watch with that of an employee who has made such comparison." "101. Maintenance of Way employees must not disturb burning fusees on or near the track placed there by trainmen."
Use of Signals, pp. 802–803. Rules 150–158 inclusive.	Eliminate all subject-matter under title and substitute following: Under title insert "See also Standard Code, AAR." ‘150. Watchmen stationed at public crossings at grade must use proper signals when necessary to stop trains. They will use stop signals to control highway traffic."
Rules for Operation of Motor, Hand Velocipede and Push Cars, p. 806. Rules 263, 264, 270, 276.	Eliminate Rule 263, and substitute: "263. Motor, hand and velocipede cars are to be used only for transporting workmen and tools. Heavy material must not be carried on them, except in emergency." Eliminate Rule 264. Eliminate Rule 270 and substitute: "270. Cars must not exceed a speed of 8 miles per hour when passing through stations or yards, over switches or through interlocking, over frogs, railroad, highway or crossings at grade. At all other points, hand cars are restricted to 10 miles per hour and motor cars as follows: Gang cars without trailers — 20 mph; gang cars with trailers—15 mph; light inspection cars center load—20 mph; light inspection cars side load—15 mph. Heavy duty inspection cars assigned to Division officers weighing 1500 lb. or more and equipped with axles 2 in. or more in diameter—30 mph. Cars must be stopped, when practicable, during passage of a train on an adjacent track." Rule 276: Change second sentence to read: "When they cannot be removed from the track to clear an approaching train, they must be protected as required by Standard Code, AAR."
Supervisors of Water Service, p. 816, Rule 420.	Eliminate and substitute: "420. Supervisors of water service report to and receive instructions from the Division Engineer."
Pumpers, p. 817, Rule 455.	Eliminate and substitute: "455. Pumpers shall keep such records on prescribed forms as may be required."
Motor Car Maintainers, p. 817, Rule 470.	Eliminate and substitute: "470. Motor car maintainers report to and receive instructions from the Division Engineer."
Supervisors of Signals, p. 819; Signal Foremen, p. 820; Signal Maintainers, pp. 821–823.	Eliminate (A Rule preceded by * is a rule of Signal Section, ARA.) Eliminate references on rules succeeding, so marked
Duties of Telegraph and Telephone Officers, pp. 823–825.	Under title eliminate: (Rules with reference to telegraph and telephone employees were prepared by the Telegraph and Telephone Section and approved by the ARA.)

Present	*Proposed*
Rules for Maintenance of Telegraph and Telephone Lines and Appurtenances, pp. 58–61, Bulletin 378. Rules 1500–1510–1536 inclusive; 1550–1560 inclusive; 1570–1581 inclusive.	Eliminate Rules 600–608 inclusive; eliminate Rule 620; eliminate Rules 625–628 inclusive; eliminate Rules 635–643 inclusive. Group all titles 1500–1510–1536 inclusive; 1550–1560 inclusive; 1570–1581 inclusive, and insert after all: "See T&T Section Manual, AAR."
Ties, p. 828. 706. Ties must be spaced according to the standard plan. All ties shall be placed square to the line of the rails. The outside ends on double tracks, and the ends on one side throughout on single track, must be lined parallel with the rail.	"706. Ties must be spaced according to the standard plan. All ties shall be placed square to the line of the rails with the center of the ties at the center of the track."
707. (Last sentence). Ties shall be adzed only when necessary to obtain a full bearing under rail or plate.	"707. (Last sentence). Ties shall be adzed only to the extent necessary to obtain a sufficient bearing under rail or plate."
Ballast, p. 832. 785. Preparatory to placing ballast, the roadbed must be widened, if necessary, to bring it to the AREA standard.	"785. Preparatory to placing ballast, the roadbed must be widened, if necessary, to bring it to the adopted standard width."
Ballasting, p. 833, Rule 797.	Eliminate and substitute: "797. In gravel, stone, chatts, chert, slag and cinders the ties must be tamped from 15 inches inside the rail out to the ends. The ends of the ties outside of the rail must be tamped first, and then, preferably, a train allowed to pass over before tamping on the inside of the rail. The space under the rail must be well tamped. The space under the center of the tie must not be tamped."
Road Crossings, p. 837, Rule 880.	Eliminate. Covered by previous rule. Renumber 880 to 881. New rule: "881. Flangeways must be kept clean of rubbish, snow, ice, and other obstructions. Defective crossing plank must be repaired."
Signals and Interlocking, p. 838, Rules 900–905 inclusive; 910–915 inclusive; 920–922 inclusive.	Under title eliminate (Reference is also made to Manual of Signal Section ARA, for additional rules), and substitute: "For maintenance of signals and interlocking, see Manual, Signal Section AAR." Eliminate Rules 900–905 inclusive 910–915 inclusive; 920–922 inclusive.
Handling Explosives. 2025. Danger signs must be conspicuously placed on all buildings and magazines in which explosives are stored.	"2025. Danger signs must be conspicuously placed on all buildings and magazines, above the roof, if practicable, in which explosives are stored."
2026. Dynamite, powder and other explosives shall be stored in fireproof magazines located at a safe distance from the company buildings, or buildings and property of others in accordance with the law, where they are not liable to be interfered with.	"2026. Dynamite, powder and other explosives shall be stored in fireproof magazines located at a safe distance from the company buildings, or buildings and property of others in accordance with the law where they are not liable to be interfered with. In states where no laws are in effect, the American Table of Distances should be used."
2028. Fuses and caps must in no case be stored in the same building with explosives.	"2028. Fuses and blasting caps must in no case be stored in the same building with explosives."

Present	*Proposed*
2029. No man should be assigned to the handling of these explosives who is not able to satisfy the Supervisor of his qualifications and previous experience in their use.	"2029. Any employee assigned to the handling of explosives must satisfy the Supervisor of his qualifications and previous experience in their use."
2031. Under no circumstances may any employee permit dynamite, detonators or any other explosives . . .	"2031. Under no circumstances may an employee permit dynamite, blasting caps or other explosives . . ."
2033. Dynamite is likely to freeze when its temperature falls below 50 deg. Fahr. . . .	"2033. Some dynamites are likely to freeze when the temperature falls below 50 deg. Fahr. . . ."
2034. Dynamite may be thawed by using an approved kettle or by placing it in a tight box and burying it in fresh manure.	"2034. Dynamite may be thawed by using an approved kettle."
2050. Inflammable Oils. All gasoline evaporates rapidly in hot weather. . .	"2050. All gasolines vaporize rapidly in hot weather . . ."
2051. (Last sentence). Lighted matches, pipes or cigaretts must be kept away from these tanks.	"2051. (Last sentence). Lighted matches, pipes or cigaretts and fires must be kept away from these tanks."
2053. Fusees, torpedoes or matches must be kept or carried only in containers provided for their protection.	"2053. Fusees, torpedoes, or matches must be kept separated in storage. Only containers provided for their protection must be used for transportation."
2054. Do not use water on an oil fire. Smother if possible with dry earth, steam or wet blankets.	"2054. Do not use water on an oil fire. Use foam, carbon dioxide or carbon tetrachloride fire extinguishers, if available, otherwise smother with steam, wet blankets or dry earth."
Science of Organization, p. 868, (Last paragraph). In the organization of the engineering forces of a railroad, the types work out into what is known as Departmental and Divisional Organizations, in the manner shown in the diagram on the following pages.	Eliminate and substitute: "A chart showing division employees in the Maintenance of Way Organization is shown below."

CHART SHOWING DIVISION EMPLOYEES
MAINTENANCE OF WAY ORGANIZATION



Appendix B

(3) RULES FOR FIRE PROTECTION

H. C. Hayes, Chairman, Sub-Committee; H. A. March, W. A. Radspinner.

Section Foremen

344. They must promptly report, giving date, train and engine number, any violation of the rule in regard to 't'he cleaning of ashpans and front end of engines on frogs, switches, trestles, or on interlocking fixtures. Fire must be promptly and thoroughly extinguished at points where ashpans are cleaned. Ashpans must be kept closed when running, and grates must not be shaken when passing over bridges and trestles."

Watchmen

357. Where fire alarms and/or fire-fighting equipment are provided, they must be familiar with the location of fire alarms and method of operation of fire-fighting equipment.

Bridge and Building Foremen

390. They must see that all fire-fighting apparatus under their jurisdiction is maintained in accordance with instructions, and make report of any unguarded fire hazard.

Painter Foremen

411. They must give special attention to the use, protection, and storage of inflammable and explosive compounds.

Water Service Repairmen or Gang Foremen

438. They must not use open lights in their work where such lights create a fire hazard.

Conduct of Work

1. The protection of the properties of the Railroad against fire is an important part of the duty of every employee and they are expected and required to give constant and personal attention to this matter.
2. Each fire must be promptly reported to the proper officer in order that thorough investigation of causes of fire can be made.
3. Fire fighting apparatus must be kept in condition for instant use, free from obstructions, and not used for other purpose than fighting fire. Its location and use must be understood by all employees concerned. Special attention should be given to condition of hose, hydrants, alarm systems and fire pumps.
4. Fire extinguishers of all types should be inspected at regular intervals and defective parts replaced promptly. Anti-freeze, hand-pump type, soda-acid and foam-type extinguishers should be discharged once each year and recharged, the date of recharging placed on tag attached to extinguisher. Carbon tetrachloride extinguishers should be given annual tests and kept filled at all times.
5. Water barrels and buckets must be kept filled and precaution taken against freezing by dissolving salt or calcium chloride in the water.
6. Dry sand with scoops must be maintained where oils, paints, or inflammable liquids are used or stored.
7. Frequent inspections should be made at ground and buildings to see that they are kept clean and free from accumulation of materials which might cause fire. Dust, birds nests, and cobwebs must not be allowed to accumulate on beams, joists, machinery and equipment in grain elevators, mill rooms, coal docks and other structures.
8. Standard metal covered receptacles should be provided for ashes, rubbish, greasy and oily rags and waste, torches, small oil supplies, and waste paper towels. Ventilated metal lockers should be provided for workmen's clothing; clothing should be suspended from hooks. Metal waste baskets should be provided in offices for scrap paper.
9. Rubbish, ashes and sweepings should not be allowed to accumulate on the property, but should be disposed of daily. Burning of rubbish and old materials must be done with due regard to fire exposure to buildings and material. A metal screen, trash burner, or incinerator should be used.

10. Combustible materials must not be used as an absorbent to catch oil drippings from bearings of machinery; metal drip pans with sand should be provided. All belts should be examined to prevent friction against combustible materials, all bearings watched for heating.

11. Fire escapes, fire lanes, fire doors and shutters must be kept free of obstructions at all times.

12. Smoking is prohibited in shops, coaling stations, piers, wharves, warehouses, storehouses, freight houses, and record rooms, and in buildings where explosives, gasoline or volatile liquids, oils or paints are used or stored.

13. Electric wiring and apparatus must be installed in accordance with the specifications of the National Electrical Code. Inspections must be made at intervals to see that they are in safe condition and kept up to standard requirements. Repairs or changes should not be made except by competent persons.

14. Electric wires must not be hung on nails or other metal fixtures, or where they will come in contact with telephone or telegraph wires. They should be supported by and hung from approved insulators.

15. Electric lamps must be equipped with vapor-proof globes in oil houses, paint rooms or other locations where volatile liquids are handled, also in grain elevators, coal docks, and other structures where explosive dust, vapors or gas may exist. The use of open lights in these locations is prohibited. Electric lamps on extension or drop cords must be equipped with wire cage guards in record stationery, storehouses, or similar facilities.

16. Fusee cabinets must be kept closed and no material allowed in them except fusees.

17. Electric lighting should be used where available. Oil lamps, when used, must be rigidly and securely supported, and must have metal fonts, with metal or porcelain shade. Oil lamps or lanterns must not be filled while burning or near any open flame. Oil supply must be kept in special metal receptacles. Excessive accumulation of explosive vapors may result if lamps are allowed to burn when nearly empty.

18. Gasoline or oil lamps or stoves and alcohol stoves should not be used except by special permission. Only those devices having the approval of the Underwriters Laboratories will be permitted.

19. All heating appliances must be thoroughly examined every fall and any defects corrected before the appliance is used.

20. Stoves must be installed at least three feet wherever possible from all woodwork, otherwise woodwork must be protected by metal shield with an air space. Combustible flooring underneath stoves and ranges must be protected by mat of sheet metal or other non-combustible material in accordance with standard plans. Stovepipes must be riveted at the joints and rigidly installed at a safe distance from combustible material. Particular attention should be given to protection where pipes pass through walls, ceilings, partitions or roofs. Where pipes are removed from chimneys, openings must be closed by tight metal caps.

21. Chimneys and flues should be built and maintained in accordance with standard plans and specifications.

22. Ashes must be removed promptly from stoves, furnaces and boiler plants, and disposed of in such manner that they will not come in contact with combustible material. Metal receptacles must be used in handling ashes.

23. Steam pipes and radiators must be properly supported and installed and kept clear of any woodwork, or other inflammable material.

24. Oils, paints, varnishes and similar compounds where possible must be kept in separate storehouse and only one day's supply allowed in any other buildings.

25. Oil houses, paint rooms, dope and reclaim houses are especially bad fire hazards and demand special attention. Inspections should frequently be made to see that all special instructions and rules in regard to them are being fully complied with.

26. Gasoline, benzine, snow melting oil or naphtha must be used from approved safety cans and never handled where artificial light other than electric incandescent lighting is used.

27. All bulk gasoline and oil stations, and gasoline loading and unloading racks must conform with the requirements of the Bureau of Explosives, and in accordance with state laws and city ordinances.

SUPPLEMENTAL

REPORT OF COMMITTEE XV—IRON AND STEEL STRUCTURES

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James Aston,
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F. E. Bates,
J. E. Bernhardt,
Adolph J. Buhler,
A. W. Carpenter,
C. H. Chapin,
O. F. Dalstrom,
R. P. Davis,
Shortridge Hardesty,
C. S. Heritage,
Otis Hovey,
F. A. Howard,
J. B. Hunley,
Jonathan Jones,
W. S. Lacher,
P. G. Lang, Jr.
B. R. Leffler,
H. S. Loeffler,
C. H. Mercer,
P. B. Motley,
F. J. Pitcher,
Albert Reichmann,
H. T. Rights,
O. E. Selby,
T. C. Shedd,
C. S. Sheldon,
I. L. Simmons,
C. E. Sloan,
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S. M. Smith,
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H. C. Tammen,
G. G. Thomas,
G. H. Tinker,
G. H. Trout,
F. E. Turneaure,
F. P. Turner,
H. T. Welty,
W. G. Williams,
A. R. Wilson,
W. M. Wilson,
Committee.

To the American Railway Engineering Association:

Committee XV—Iron and Steel Structures, submits the following supplemental report on Rules for Rating Existing Iron and Steel Bridges, to replace the Rules submitted in original report, published in Bulletin 382.

The Committee on Iron and Steel Structures,
G. A. Haggander, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

O. E. Selby, Chairman, Sub-Committee; J. E. Bernhardt, C. H. Chapin, O. F. Dalstrom, C. S. Heritage, P. B. Motley, I. L. Simmons, C. E. Sloan, G. H. Trout, R. A. Van Ness, A. R. Wilson.

Your Committee recommends elimination from the Manual of the material under "Copper-bearing Steel for Structural Purposes", appearing in Supplement to the Manual, 1932, Bulletin 347, page 41.

Also elimination of the "Rules and Unit Stresses for Rating Existing Bridges," on pages 1248 to 1250 inclusive, of the current Manual, and substitution therefor of the following "Rules for Rating Existing Iron and Steel Bridges."

The revision of these rules was the work of the following Special Sub-Committee: B. R. Leffler, Chairman, Sub-Committee; F. E. Bates, A. W. Carpenter, C. H. Chapin, O. F. Dalstrom, Otis Hovey, J. B. Hunley, H. S. Loeffler, P. B. Motley, C. S. Sheldon, C. E. Sloan, S. M. Smith, G. H. Tinker, G. H. Trout, F. E. Turneaure.

Bulletin 384, February, 1936.

RULES FOR RATING EXISTING IRON AND STEEL BRIDGES—1936

Carrying Capacity

1. The carrying capacity of a bridge shall be determined by the computation of stresses based on authentic records of the design, details, materials, workmanship, and physical condition, including data obtained by inspection (and tests if the records are not complete). For a specific service the location and behavior under load shall be taken into account.

Inspection

2. An inspection of the bridge shall be made to determine:

   (a) Whether the actual sections and details conform to the drawings.
   (b) Any additions to the dead load not shown on the plan, such as heavier deck or rail, walks, pipe lines, conduits, signal devices, and wire supports.
   (c) The position of the track with respect to the center line of the bridge.
   (d) Any loss of metal due to corrosion and wear. This determination should be made by caliper measurements after removal of scale.
   (e) The physical condition, noting such defects as unequal stress in tension members, loose rivets, worn pins, crooked or damaged members, and cracked parts; also the condition of braces intended to limit the slenderness ratio of columns or compression flanges.
   (f) The condition of pin plates of tension members, especially those inside other members.
   (g) The condition of slender tension members, such as eye-bars, with special reference to the effects of vibration of the member caused by passing trains or by wind.
   (h) The condition of floor beams and their connections to truss members, particularly where the connection has been shaped to clear eye-bar heads or the bottom chord.
   (i) The condition of stringer connections, especially for shallow stringers.

Computation of Stresses

3. The computation of stresses shall be made for the details as well as for the main members, giving particular attention to:

   (a) The increased load carried by any truss, girder, or floor member due to the eccentricity of the load. This applies to bridges on tangent where the tracks are off center as well as to bridges on curves.
   (b) Spacing of web stiffeners, lacing and forked ends of compression members, eccentricity of riveted joints and connections, unequal stress in tension members, and secondary stresses.
   (c) Pin plates of tension members. The following rules are given as a guide, when the body of the member is carrying the limiting stress:
      1. The net section through the pin hole transverse to the axis of the member should be 40 per cent. greater than the net section of the member.
      2. The net section beyond the pin hole on any line parallel to the axis of the member should be not less than three-fourths of the net section of the member.

Loads and Forces

4. Bridges shall be computed for the following loads and forces:

   Dead load
   Live load
   Impact
   Centrifugal force
   Other lateral forces
   Longitudinal force

Dead Load

5. The dead load shall be the weight of the bridge including the deck and track, together with that of any other fixed loads.

Live Load

6. The live load shall be one of the Cooper's E series or else a load consisting of a specific locomotive or other equipment, depending on the purpose for which the rating is desired.

If the live load is to be a specific locomotive and cars (or other equipment) complete data shall be obtained, including the spacing of the axles and the static load on each axle. If the precise method of determining impact is to be used, the data shall include the counterbalance report of the locomotive.

Impact

7. To the computed static live load stresses there shall be added the impact produced by the live load in motion. Impact shall not be added to the lateral forces.

8. The impact ordinarily to be provided for shall be determined by the rules for impact in the AREA Specifications for Steel Railway Bridges, except that the maximum limit of 100 per cent. shall not apply.

Precise Determination of Impact

9. A more precise determination of the impact produced by a specific steam locomotive may be made by computing separately the following effects:

(a) Track Joint Effect
(b) Lurching Effect
(c) Hammer Blow Effect

The total impact shall be the sum of these three effects, computed as follows, but not less than 15 per cent. of the static live load.

(a) Track Joint Effect

The track joint effect shall be taken as that produced by a concentrated load, acting on each rail at the center of the span, equal to:

$$\frac{W\ S^2}{20000}$$

in which

$W =$ the maximum wheel load, in pounds.
$S =$ the speed in miles per hour, but not greater than the synchronous speed.

(b) Lurching Effect

The lurching effect is the increase of load on one rail with a corresponding decrease on the other. It shall be taken as 20 per cent of the static live load and be distributed to the supporting members.

(c) Hammer Blow Effect

The hammer blow effect is the centrifugal force due to the revolving over-balance on the locomotive drivers. It is determined as follows:

1. For spans 20 feet or less in length, the loaded frequency is so high that synchronous speeds cannot be attained, the dynamic magnification is unity, and at any speed N

$$H = 100\,\beta\, N^2$$

2. For spans the loaded frequency of which is such that synchronous or higher speeds may be attained, but on which locomotive spring action does not occur, at synchronous speed

$$H = 100 \frac{\beta n}{2p}$$

3. For spans the loaded frequency of which is such that synchronous and higher speeds may be attained, and on which locomotive spring action may occur:

   (a) When the speed corresponding to the second higher frequency, *f*, is attained,

$$H = \frac{100}{2pf} (\beta f^2 - 0.07)$$

   (b) When the speed corresponding to the second higher frequency cannot be attained, at any speed N

$$H = \frac{100}{2pf} (\beta N^2 - 0.07)$$

The largest value of H obtained by the formulas in paragraphs 2 and 3 shall be taken.

Note.—With an assumed maximum speed of 7 r.p.s., the formulas in paragraph 3 probably will give larger values of H for deep spans 60 to 90 feet in length, and for shallow spans 40 to 80 feet in length. For lower speeds the formula in paragraph 2 will govern over a greater range in length.

4. For all spans, at speeds less than the synchronous speed

$$H = \frac{100\,\beta N^2}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(2pn\frac{N}{n}\right)^2}}$$

Note.—This formula may be used to determine the permissible speed corresponding to a limited impact.

In the foregoing expressions for hammer blow effect:

H = hammer blow effect, in percentage of the static live load.
L = length of span, in feet.
d = central deflection of the span, in inches, due to the dead load.
D = central deflection of the span, in inches, due to the static live load when placed in the position for maximum moment.
D_h = central deflection of the span, in inches, due to the hammer blow of the locomotive drivers, at 1 r.p.s., acting statically at the center.

The total hammer blow of the locomotive is 1.414 times the hammer blow on one side as given by the counterbalance report.

N = number of revolutions per second of the locomotive drivers.
$n = \sqrt{\frac{12}{d + D}}$ = the frequency of the span, vibrations per second, under the load being considered, locomotive springs not acting.

Synchronous speed is the speed at which N is equal to n.

$\beta = \frac{D_h}{D}$ = ratio of the deflection due to the hammer blow at 1 r.p.s. to the static live load deflection.
p = the damping constant of the span which may be expressed as follows:

For girder spans, $p = \frac{3.2}{L + 32}$

For truss spans, $p = \frac{14}{L + 350}$

$f = \sqrt{(4.9 - 0.03L)\ (n^2 + 5)}$ = the second or higher critical frequency resulting from locomotive spring action.

For the trusses or girders of through spans, all stringers, and the girders of deck spans (if the stringers or the girders of deck spans are so braced that they act in unison) one-half of the total hammer blow of the locomotive shall be assumed as acting on each stringer, girder, or truss.

If the stringers or girders are directly under the rail and are so inadequately braced that they oscillate independently of one another, the hammer blow from one side of the locomotive shall be assumed as acting on each stringer or girder.

The hammer blow effect, computed as above for bending, shall be used for shear, and is applicable only to steel spans simply supported.

Note.—For comprehensive discussion of Impact, see A.R.E.A. Bulletin No. 380, and bibliography in Appendix C thereof.

Centrifugal Force

10. On curves, the centrifugal force, based on the actual speed of operation, and assumed to act 6 feet above the rail, shall be taken as a percentage of the static live load equal to:

$$0.00117 S^2 D$$

in which

$S =$ speed in miles per hour.
$D =$ degree of curve.

Wind

11. The wind force shall be considered as a moving load, acting in any horizontal direction. The wind force on the bridge shall be taken at 30 pounds a square foot of:

(a) One and one-half times the vertical projection of the floor system and girders.
(b) The vertical projection of all trusses.

but not less than 200 pounds a linear foot of loaded chord or flange, and 150 pounds a linear foot of unloaded chord or flange.

(c) The vertical projection of columns and tower bracing.

The wind force on the train shall be taken as 300 pounds a linear foot on one track, applied eight feet above the top of the rail.

Sway of Locomotives

12. The lateral force to provide for the effect of the sway of locomotives (in addition to the other lateral forces), shall be a moving concentrated load equal to one-sixteenth of the weight of one locomotive without tender, applied at the top of the rail in either lateral direction at any point of the span.

Lateral Force Due to Impact

13. If there is superelevation in the track, the horizontal component of the impact shall be taken as a lateral force applied at the top of the rail, equal to 5 per cent. of the total impact.

Longitudinal Force

14. The longitudinal force resulting from the starting and stopping of trains shall be the larger of:

(a) Force due to braking.
    Fifteen per cent of the static live load.
(b) Force due to traction.
    Twenty-five per cent of the total weight on the driving wheels, without impact.

The longitudinal force shall be taken on one track only and shall be assumed to act 6 feet above the top of the rail.

For bridges where, by reason of continuity of members or frictional resistance, much of the longitudinal force will be carried directly to the abutments (such as ballasted deck bridges of only three or four spans), only one-half of the longitudinal force shall be considered effective.

Live Load and Impact on Multiple Track Bridges

15. The application of the live load and the impact to multiple track bridges shall be as specified in the AREA Specifications for Steel Railway Bridges.

Permissible Stresses

16. The permissible unit stresses resulting from the loads and forces described in the preceding articles are the following, in which

$k = 0.8$ of the yield point for open hearth steel
$= 0.8$ of the yield point for wrought iron
$= 0.7$ of the yield point for Bessemer steel

The yield point shall be taken at not more than 0.55 of the ultimate strength.

	Pounds per Square Inch	
	Steel	*Wrought Iron*
Axial tension, net section	k	k
Tension in extreme fibers of rolled shapes, girders, and built sections, net section....	k	k
Axial compression, gross section: (For columns centrally loaded and with values of $\frac{l}{r}$ not greater than 140)		
Riveted ends	$\frac{k}{18000}\left(15000 - \frac{1}{4}\frac{l^2}{r^2}\right)$	$\frac{k}{15000}\left(12500 - 0.21\frac{l^2}{r^2}\right)$
Pin ends	$\frac{k}{18000}\left(15000 - \frac{1}{3}\frac{l^2}{r^2}\right)$	$\frac{k}{15000}\left(12500 - 0.28\frac{l^2}{r^2}\right)$
$l =$ length of member in inches. $r =$ least radius of gyration of the member in inches.		
For columns with values of $\frac{l}{r}$ greater than 140 and for columns of known eccentricity, see Appendix on Column formulas of the AREA Specifications for Steel Railway Bridges, using appropriate values for y, f, and E.		
Compression in extreme fibers of rolled shapes, girders, and built sections, subject to bending, gross section	$\frac{k}{18000}\left(18000 - 5\frac{l^2}{b^2}\right)$	$\frac{k}{15000}\left(15000 - 4\frac{l^2}{b^2}\right)$

	Pounds per Square Inch	
	Steel	Wrought Iron
l = length, in inches, of the unsupported flange between lateral connections or knee braces. b = flange width, in inches.		
Tension in extreme fibers of pins, assuming loads concentrated at centers of bearings..	$2k$	$2k$
If the members are packed close together on the pin, the bending stress may be disregarded unless the tension in the extreme fiber exceeds 60,000 for open-hearth steel, or 50,000 for wrought iron and Bessemer steel.		
Shear in plate girder webs and rolled beams, gross section..	$0.75k$	$0.75k$
Shear in rivets and pins.......	$0.9k$	$0.9k$
The permissible values for shear shall be reduced 20 per cent. for countersunk rivets, floor connection rivets, and turned bolts.		
Bearing on rivets, pins, outstanding legs of stiffener angles, and other steel parts in contact, may be disregarded unless there is visible deformation of the parts in contact.		

In the absence of definite records of tests, the yield point shall be taken as 30000 for steel and 25000 for wrought iron.

Stresses in plate girders may be computed either by the moment of inertia of their net sections or by assuming that the flanges are concentrated at their centers of gravity. In the latter case, one-eighth of the gross section of the web, if continuous or properly spliced, may be considered as flange section. Girders having unusual sections shall be computed by the moment-of-inertia method.

Conclusions

17. If the stresses exceed those permissible under these rules, the speed shall be so restricted, if practicable, that the permissible stresses will not be exceeded. If the speed cannot be so restricted, or if the design or the physical condition of the bridge makes it necessary, it shall be strengthened or renewed. When the permissible stresses are closely approached, or when the physical condition of the main members or the details is not good, the bridge shall be kept under close inspection as long as it is continued in service.

MONOGRAPH

IMPACT IN STEEL RAILWAY BRIDGES OF SIMPLE SPAN

As Derived From Tests Made on The Cleveland,
Cincinnati, Chicago & St. Louis Railway
1931-1934

By J. B. HUNLEY
Engineer of Bridges and Structures

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TRUSS SPANS

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338 “ “ “ “ “ “ “ —Span 3 830
224 “ 0 “ “ “ “ “ — “ 4 832
207 “ 4 “ “ “ “ “ — “ 5 837
184 “ 0 “ “ “ “ “ — “ 6 839
150 “ “ “ Double “ “ “ — “ 7 845
140 “ “ “ Single “ “ “ — “ 8 850
138 “ “ “ “ “ “ “ — “ 9 855
125 “ “ “ “ “ Deck “ — “ 10 860
122 “ 3 “ “ “ Through “ — “ 11 863
110 “ 0 “ “ “ “ “ — “ 12 866

DECK GIRDER SPANS WITH OPEN FLOOR

103 ft. 8 in. Single Track Deck Girder—Spans 13 and 14 869
100 “ 0 “ “ “ “ “ — “ 15 “ 16 869
96 “ 6 “ “ “ “ “ — “ 17 “ 18 869
91 “ 2 “ “ “ “ “ —Span 19 869
83 “ 0 “ “ “ “ “ — “ 20 883
77 “ 6 “ “ “ “ “ — “ 21 883
70 “ 0 “ “ “ “ “ — “ 22 883
64 “ 7 “ “ “ “ “ — “ 23 883

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50 “ “ “ “ “ “ “ —Span 29 903
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DECK GIRDER SPANS WITH SOLID FLOORS

125 ft. 0 in. Single Track Deck Girder—Spans 32 and 33 919
86 “ 6 “ “ “ “ “ — “ 34 “ 35 926
70 “ 0 “ “ “ “ “ — “ 36 “ 37 930
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86 Drawing of 70 ft. 0 in. Deck Girder..... " 36 " 37 931
87 Oscillations and Magnifiers .... " 36 " 37 931
88 Drawing of 52 ft. 0 in. Deck Girder.....Span 38 935
89 Oscillations and Magnifiers .... " 38 935
90 Drawing of 52 ft. 0 in. Deck Girder..... " 39 937
91 Oscillations and Magnifiers .... " 39 937

IMPACT IN STEEL RAILWAY BRIDGES OF SIMPLE SPAN

As Derived From Tests Made on The Cleveland, Cincinnati, Chicago & St. Louis Railway
1931–1934

By J. B. HUNLEY

(I) FOREWORD

For some time there has been a question, in the minds of many Engineers, as to the justification for the continued use of the present impact formula*. It assumes that all locomotives will produce the same amount of impact on any span of a given length, and disregards altogether the individual characteristics of both the equipment and the structure. Its use, for determining the capacity of many existing bridges, usually leads to a drastic speed or load restriction, although the span being investigated may show no evidence of overstress.

On the Cleveland, Cincinnati, Chicago and St. Louis Railway there were several bridges, apparently in good condition, but which, when rated in accordance with the generally accepted practice, would be limited to certain power or be restricted as to speed for heavier locomotives. Speed restrictions or renewals are costly, and it seemed worth while to make some effort to determine the actual effect of the locomotives in use on these spans, before recommending their replacement. It was for this purpose alone that the tests which will be described were first undertaken in 1931. About 15 bridges were involved, most of which were tested and found to be of sufficient capacity to take the desired increase in loading without speed reduction, and their renewal has been indefinitely postponed.

A study of the early tests revealed the possibility of obtaining more valuable information, as to the effect of moving loads on bridges, than the mere measure of the recorded amount of impact caused by some particular locomotive, and the tests were continued during the succeeding summers, until a total of 39 spans had been investigated. It is hoped that the results of these tests, as presented here, and the conclusions reached as to methods of estimating impact in bridges, will be of value to other Engineers.

The dynamic effects of moving loads on railroad bridges have been recognized for many years, and have been a subject of much study and investigation. We have had a much better understanding of the character and magnitude of the forces producing these effects, than of the exact effect resulting from any one of these forces.

Many tests have been made, some of them in a most painstaking manner, from which the various impact formulas have been derived. These formulas are usually a mathematical expression of some curve lying well above and enclosing the maximum plotted values of impact, determined experimentally, with one or several types of engines on various spans. The lower values, frequently disregarded altogether, were probably quite as logical and correct as the higher values, had we known enough about the theory

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Note.—* This report was written before the new impact formula was adopted at the Convention in March 1935. The "present formula" referred to is, Impact $= \frac{30,000}{30,000 + L^2}$

of vibrations, to have properly interpreted them. Such formulas commonly express the impact allowance in terms of the span length only, while its length may be of importance only insofar as it affects certain other factors. For many spans, they are apt to be on the safe side, almost to the point of extravagance, and while they may not be so objectionable for designing new bridges, they are totally unsuited for determining, with any accuracy, the capacity of existing bridges.

Several experimenters in the past have accounted, at least in part, for some of the results obtained experimentally. As early as 1885, Professor S. W. Robinson, in that part of his report to the Railroad and Telegraph Commissioner of Ohio[1] dealing with vibration of bridges, made a clear statement as to the various forces producing impact. He not only recognized the effect of synchronous speeds, but gave formulas for computing the natural loaded frequencies of bridges. He even suggested certain changes in design, by which he hoped to minimize the dynamic effect, one of them being the introduction of friction in the end bearings, which would indicate that he appreciated the effect of damping. His deflection and oscillation diagrams, made with a "recording indicator", are quite good, showing vibrations, set up by the passage of the locomotive and cars, just about as we find them to-day.

The most complete series of tests made heretofore in this country, is that of the Committee on Impact of the A.R.E.A., under the direction of F. E. Turneaure, Dean of the College of Engineering, University of Wisconsin. The results were published in 1911,[2] and these tests were the origin of the impact formula now in most general use. Here again we find ample evidence of the effect of synchronous speeds and locomotive counterbalancing. The report contains an interesting and valuable discussion, by Dean Turneaure, on the theory of oscillations and span frequencies.

Later tests have been conducted by the Indian State Railways and in the various reports[3] we find every evidence of a clearer understanding of theory. The development of their formula takes into account nearly all of the principal causes of impact. Presumably for lack of more definite information, some rather arbitrary assumptions are made as to certain of these factors, but at least they are recognized, although this may not be apparent in the proposed simplified working formula, as the amount of impact is expressed in terms of span length only.

One of the most valuable contributions to the subject is the report of the Committee of the Department of Scientific and Industrial Research on Bridge Stresses,[4] published at London, 1929. While the data obtained from the tests are not given in detail, we meet here for the first time, with an effort to account for, by theory, the effect of each of the various forces acting upon the bridge.

Obviously, the tests were most carefully made with the best available instruments. Many deflection and stress records are reproduced, illustrating several phases of the problem and, finally, tables of equivalent loads for designing bridges are included, the intensity of load varying with the speed and locomotive counterbalancing.

Perhaps the most valuable part of this report is the theoretical discussion, which deals with the subject in an entirely new and illuminating manner. An attempt is made to set up definite values for the effect of damping, not only from the span itself but from the action of the locomotive springs. The presence of these neutralizing forces has been suspected, but so little has been known about them that most of us have considered them simply as something thrown in for good measure on the side of safety. It is strange that no attempt has heretofore been made to isolate and examine this most important factor, for it is now quite evident that, with sufficient knowledge as to the amount and kind of damping present, the dynamic effect of any locomotive, of known weight and counterbalancing, on almost any ordinary bridge, can be closely estimated.

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[1] For references, see List of References in Appendix C.

Theory seemed to be well substantiated by the British tests, but the type of locomotives used and the bridges tested were quite different from those with which we have to deal. An examination of the first of our tests indicated that more information, particularly as to the bridge damping coefficients, would have to be obtained from additional tests, using our own type of equipment and bridge spans. Were we fortunate enough to find that the behavior of a few typical spans, which might be tested, conformed equally well with theory, after taking into account the new coefficients derived from such tests, it was felt that, with theory so well verified, this new method might be used with confidence for estimating the amount of impact, on any other span of the same general type, under any specified loading.

The result was more satisfactory than had been expected, and the data obtained from these tests were the basis of the new Impact Formula tentatively recommended by the Committee on Iron and Steel Structures,[5] in the proposed revision of the Specifications for Steel Railway Bridges, 1934.

There is still much work to be done, and the suggested method of determining impact, which will later be described, is not offered as the final and complete solution of this important problem. It does seem, however, that the time has come when we can safely and profitably discard the old empirical formulas, using in their stead more rational methods which, in a large part at least, seem so well proven. Further refinements can later be incorporated, or some better method developed, when our knowledge of the subject is more complete.

The writer makes no claim for originating any new theories, as he has depended largely upon the work done by others. The theory of vibrations, in a structure, is a complex subject, and when one of the simpler solutions could be safely used it has been adopted, even though it might conflict somewhat with pure theory. A locomotive is, in itself, a complicated mechanism, and when we consider its action on a bridge we have so many variables, about which, at present, we lack full knowledge, that the error in many of the assumptions, which it is necessary to make in arriving at a complete theoretical solution, may put us farther from the mark than some simpler formula which may ignore or lump together some of these unknowns.

The original test records are too numerous to reproduce, but an attempt will be made to give all of the pertinent data obtained, in such form that they can be used by anyone who may be inclined to try some other and perhaps better method, or may wish to supplement these tests by others of his own. The field records will be preserved for further study.

(II) SPANS TESTED

The tests were started in the summer of 1931, and were undertaken primarily for the purpose of finding, if possible, the actual load-carrying capacity of some of our lighter steel bridges, the use of which had been, or would be, restricted to certain classes of power, or perhaps would be condemned, if rated by the usual impact formula. At that time there was no intention of conducting an elaborate series of tests, and consequently no fixed program was laid out, the spans selected being those in which we were especially interested from the standpoint of safe operation of the equipment then in use.

However, these questionable spans covered quite a range in length, being from 50 to 225 feet long, and the results obtained, when examined in the light of these new theories, were so interesting that it seemed well worth while, as the opportunity presented itself, to test others, even though they were not under suspicion. It was hoped that, with this additional information, we would be able to estimate, with a fair amount of certainty, the impact on any other span, under any engine, without making actual tests on that span.

The work was continued during the summers of 1932 and 1933, tests being re-run on a few of the bridges where insufficient or questionable data had been obtained in the first instance. Owing to the general reduction in force, the work could not be carried on with any regularity, but only when the few men required could be spared from their regular duties, but eventually about 2100 records were collected from tests on 39 spans.

Most of the work was done on open deck bridges, that is, those on which the wooden ties are supported directly by the stringers or girders. With one exception, they were all single track spans.

Of these open deck bridges, there were 19 deck plate girders, ranging in length from 40 to 104 ft., 11 through truss spans, both riveted and pin connected, from 110 to 547 ft. long, and one pin connected deck truss, 125 ft. in length. Some tests were made, at slow speeds, on several very light structures in switching territory, but this was done largely for the purpose of checking deflections, stresses, and truss action, as part of an investigation as to the possible use of heavier power at slow speed, and these tests are not reported.

Tests were also made on 8 deck plate girders having concrete decks and ballasted track. These spans ranged in length from 52 to 125 ft., and carried a single track.

A list of the spans tested, together with data as to their principal dimensions, design load, stresses, etc., is given in Table I. In Appendix B, there will be found a general drawing of each span, giving more detailed information. It will be noted that a few of the spans are alike, particularly on double track bridges. Not only did we desire to find out if duplicate spans would act alike, but testing on both tracks expedited the work, permitting us to use trains in both directions, with a greater range in speed. Except where there was evidence of some difference in the behavior of two identical spans, the results have been combined.

The spans were both light and heavy, the load for which they were designed ranging from Cooper's E-30 to E-70. The design loading, as given in Table I, is not necessarily a true measure of capacity as, in the earlier specifications, there was used, with this light loading, the low live load unit stress of 10,000 lb., with a small impact allowance. In the later specifications (1910 and after), the loading and impact allowances were increased and the designing stress raised to 18,000 lb.

With the exception of very short spans, the range in length of the open-floor bridges, which were tested, embraces almost any simple span which has been built, or is likely to be built in the future. Tests on spans of less than 40 ft. in length were not undertaken, as it is usually impossible to even approach synchronous speed on such structures, and, due to the small mass of the span, the oscillations would likely be so obscured by other vibrations that, with the available apparatus, the tests would have been of but little value.

On the girders with solid floors, the deck consisted of a concrete slab which had been poured in place, and it was found, in each instance, that the deck acted as so much additional flange section, giving small deflections and high frequencies. On the shortest spans, which were 52 ft. long, the critical speed, with the heaviest power now in service, would be about 150 m.p.h., so that tests on shorter spans, with similar decks, would scarcely be worth while. The longest span tested, 125 ft., is about the limit in length

TABLE I SPANS TESTED

Sheet Nº 1

TRUSS SPANS

Span No.	Type	Span C to C of Bearings	Depth C to C of Chords	Span/Depth	No of Tracks	No of Trusses	Date	Material	Design Data					Wght. per Ft. Lbs			Total Wght of Span Lbs
									Loading (Cooper)	Unit Chord Stress				Steel	Deck	Total	
										D.L	L L	Imp.	Total				
1	Riv. Thru	547'-4"	90'-0"	6.08	1	2	1928	Silicon St.	E.65	11520	8900	1780	22200	8000	580	8580	4,697,500
2	" "	"	"	"	"	2	"	Silicon St	"	"	"	"	"	"	"	"	"
3	Riv "	338'-4"	60'-0"	5.64	1	2	1928	O.H.Steel	E.65	5900	7520	1560	14980	4850	570	5420	1,834,600
4	Pin Con Thru.	224'-0"	40'-0"	5.60	1	2	1900	Soft Steel	E.38.5	+4270 ○4620	8050	350	+12670 ○13020	1950	+ 350 ○ 540	+2300 ○2490	+ 512900 ○ 658000
5	Riv. Thr.	207'-4"	40'-0"	5.18	1	2	1928	O.H.Steel	E.70	4440	8390	3450	16280	3780	570	4350	902300
6	Pin Con.Thru	184'-0"	30'-8"	6.00	1	2	1904	O.H.Steel	E.51.6	+3310 ○3540	7670	400	+11380 ○11610	2330	+ 355 ○ 545	+2685 ○2875	+ 495600 ○ 619700
7	Riv. Thru	150'-0"	32'-0"	4.69	2	2	1913	O.H.Steel	E.60	3580	9460	4820	17860	4820	895	5715	857600
8	" "	140'-0"	28'-0"	5.00	1	2	1913	O.H.Steel	E.60	3310	8570	5940	17820	2365	555	2920	408700
9	Riv. Thru	138'-0"	28'-0"	4.93	1	2	1916	O.H.Steel	E.60	3310	8640	6000	17950	2440	450	2890	398300
10	Pin Con. Dk	125'-0"	21'-0"	5.95	1	2	1894	Soft Steel	E.37.0	3680	9400	700	13780	1355	480	1835	229500
11	" " Thru	122'-3"	27'-3"	4.48	1	2	1892	Soft Steel	E.30.2	3080	8100	810	11990	1100	420	1520	186000
12	Pin.Con.Thru	110'-0"	25'-0"	4.40	1	2	1893	Steel & W.I.	E.43.2	2900	9800	0	12700	1300	380	1680	184800

NOTE:- + Weight of Deck-Tests-Series 1
○ " " " - " -Series 2 and 3

TABLE I SPANS TESTED

Sheet 2

DECK GIRDERS – OPEN FLOOR

Span No.	Span		Depth Overall	Span/Depth	No. of Tracks	No. of Girders	Date	Material	Design Data (Web included)					Wght per Ft.			Total Wght of Span
	Overall	C to C Bearings							Loading (Cooper)	Unit Stress				Steel	Deck	Total	
										D.L.	L.L.	Imp.	Total				
13	103'-8"	100'-8"	8'-8⅜"	11.51	1	2	1930	O.H.Steel	E.70	2460	8820	6590	17870	2000	510	2510	260200
14	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
15	100'-0"	98'-0"	9'-5"	10.39	1	2	1901	O.H Steel	E.52.2	2370	7770	740	10880	1645	410	2055	205500
16	"	"	"	"	"	"	"	"	"	2400	"	"	10910	"	430	2075	207500
17	96'-6"	94'-2"	8'-3½"	11.34	1	2	1900	O.H.Steel	E 52.3	2300	9530	920	12750	1165	480	1645	158 800
18	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
19	91'-2"	88'-11"	9'-1¾"	9.73	1	2	1924	O.H.Steel	E.70	2000	8900	7050	17950	1650	440	2090	190500
20	83'-0"	80'-8"	9'-3"	8.72	1	2	1910	O.H.Steel	E.60	1970	8290	6520	16780	1410	510	1920	159400
21	77'-6"	75'-6"	8'-3¼"	9.13	1	2	1913	O.H Steel	E.60	1720	8070	6450	16240	1245	510	1755	136000
22	70'-0"	68'-0"	7'-9¼"	8.75	1	2	1906	O.H.Steel	E.51.9	1380	6450	830	8660	1075	470	1545	108100
23	64'-6"	63'-0"	6'-9¼"	9.31	1	2	1897	Soft Steel	E 33.0	1600	6250	850	8700	760	450	1210	78000
24	64'-8	62'-8"	6'-8¾	9.30	1	2	1905	O.H.Steel	E.52.3	1400	7650	1050	10100	940	450	1390	89900
25	64'-0"	61'-9"	6'-2⅝"	9.91	1	2	1898	Soft Steel	E.33.0	1650	6220	850	8720	800	450	1250	80000
26	53'-3"	52'-0"	5'-4½"	9.69	1	2	1897	Soft Steel	E.32.4	1490	6500	1050	9040	685	430	1115	59400
27	50'-0"	48'-0"	4'-7½"	10.38	1	2	1913	O.H.Steel	E. 60	1320	8500	7350	17170	945	490	1435	71800
28	50'-0"	"	"	"	"	"	1916	" "	"	1290	"	"	17140	"	450	1395	69800
29	50'-0"	48'-4"	6'-8⅛"	7.23	1	2	1902	Soft Steel	E.54.0	1120	7170	1230	9520	850	450	1300	65000
30	40'-0"	38'-6"	4'-0⅞"	9.45	1	2	1905	Soft Steel	E.57.5	950	7470	1540	9960	770	450	1220	48800
31	40'-0"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"

TABLE I SPANS TESTED

Sheet 3

DECK GIRDER - CONCRETE DECK BALLASTED FLOOR

Span No.	Span		Depth Overall	Span/Depth	No. Trks.	No. of Girders	Date	Material	Design Data					Wght per Ft Lbs			Total Wght. of Span Lbs.
	Overall	C. to C. Bearings							Loading (Cooper)	Unit Stress				Steel	Deck	Total	
										D.L.	L.L.	Imp.	Total				
32	125'-0"	122'-6"	11'-1⅛"	11.04	1	2	1927	Carbon Steel		5500				2310	3865	6175	771,900
33	"	"	"	"	1	2	"	" "		"				"	"	"	"
34	86'-6"	84'-4'	7-11⅜" 7-11⅞	10.59	1	4	1929 1899	" "	E-70	4780	5620	4530	14030	2360	5600	7960	688,500
35	"	"	"	"	1	4	"	" "	"	4720	"	"	13970	"	5500	7860	679590
36	70'-0"	67'-9"	8'-1"	8.65	1	3	1929	" "	"	3950	5510	4780	14240	1770	5300	7070	494,900
37	"	"	"	"	1	3	"	" "	"	"	"	"	"	"	"	"	"
38	52'-0	50-0 50-4¼' 50 5	6 7 6-9⅜ 6 ⅞	787	1	5	"	" "	"	4080	6140	5650	15870	1400	5700	7100	369200
39	·	50'-4¼	6-9⅜	742	1	3	"	" "	"	3650	5480	5040	14160	1390	5700	7090	368680

NOTE:- Span-Depth Ratios and Unit Stresses are based on section of Steel only- For combined section of Steel and Concrete see Table VI

for such girders. Tests on other spans, in which the ballasted track is carried on a timber floor or precast concrete slab simply resting on the top flanges, would be of interest.

Generally speaking, the spans were in first-class condition, except two or three of the older pin connected trusses, in which there was pin wear, and unequal distribution of stress between pairs of eye-bars. The expansion bearings probably represented an average condition existing on most railroads. Practically all girder spans, under 80 ft. in length, had flat sliding bearings, some of which were undoubtedly "frozen". The longer girders and all trusses had roller bearings, but it is only in the bridges built after 1910 that we find expansion rollers of adequate size. In the older spans they were small and sometimes badly rusted.

The masonry substructure was usually found in good condition, although, in a few structures, the bridge seats did not provide uniform or unyielding support. This was particularly true of the shorter spans, the weight of which was not great enough to bring the bearings into solid contact under the dead load only. This resulted in more or less "chattering" under the passage of the trains. Where heavy ballast lifts had been made, some of the girders had been raised on timber blocking, usually about 8 in. thick. This did not seem to affect the oscillation of the span to any noticeable extent, but did make necessary a correction in the crawl or static live load deflections.

Since most of the bridges tested were on the main line divisions, and subject to heavy traffic at high speeds, the ties and rail of the deck were in good condition, the rail joints being about what might be expected in such track. More often than not, however, the track was found slightly off the center of the bridge.

(III) TEST TRAINS AND LOCOMOTIVES

The particular period, during which this work was undertaken, was a most inopportune time to ask for special test engines and cars, so that, with a few exceptions, all readings were taken during the passage of some regularly scheduled train. With the present comparatively light traffic, not many tests could be had in any one day, and with the several classes of locomotives in service but few tests would be had of any one class, and such runs, normally, were likely to cover a very narrow range of speed. This required staying at each bridge until what seemed to be sufficient data had been collected. Even then it might be found, when the records were later worked over in the office, that runs, at the very speed most needed, had not been encountered. This meant going back for additional tests, whenever it could be arranged.

On the other hand, the use of these regular trains had its advantage, as the tests more nearly represent actual service conditions. With special test equipment it is unlikely, even in the most prosperous times, that more than three or four locomotives from the different classes would have been assigned for the work. Taking the trains as they came, use was had of about 300 engines, of 43 different classes, in various states of repair. The records were taken during the passage of the entire train, which gave much information as to the effect of practically all types of cars, under various conditions of loading; something which we would not have had with special trains. The ideal arrangement, no doubt, would be to use both regular and special equipment.

In a few instances, when it was particularly important and not too inconvenient, an engine, or an engine and a few cars of known weight, would be borrowed from a work train or local, to make several runs over a wide range of speeds. This saved a great deal of time, and often made possible a comparison of a series of tests with one locomotive, with tests from several locomotives of that same class.

There was a considerable difference in speed between passenger and freight trains, and usually some difference between eastward and westward movements. If, with these natural variations, a satisfactory range was not obtained, it was frequently possible to arrange for a few trains to run either faster or slower, than was customary, to give a few needed speeds. Even though but few tests might be obtained on one class of locomotive, it was possible, where several classes were enough alike to produce about the same static deflection or span frequency, to combine them, after reducing the various amounts of overbalance, in their counterweights, to some common denominator.

These regular trains carried a variable engine tender load, particularly between the movements in opposite direction, and the cars, especially in freight trains, were of many types, carrying any load up to capacity. On spans of more than 60 ft. in length, it was necessary to take this into account. From the coal and water records and known fuel consumption characteristics of the various types of locomotives, it was possible to arrive at a close approximation of the tender loading at the time of the test. The initial, number and gross weight of each of the first few cars were obtained from the train reports. At times it was possible to have a run at slow speed, and with cars of known weight, or to measure the deflection under some known quiescent load. With such information, the true deflection factor of the span could be determined, from which the deflection under any other loading could be calculated.

In Appendix A will be found a table giving most of the characteristics of the locomotives used in these tests. Diagrams showing the wheel spacing and axle loading are given, together with information as to dead and live weights, counterbalancing, calculated spring frequencies, etc. For the Big Four and Pennsylvania engines, the counterbalancing represents the average of the engines of each class. The amount of counterbalance on any individual locomotive, of one class, supposedly may vary from 5 per cent to 10 per cent either way from the average, although this difference was scarcely noticeable in its effect. For the Erie engines, which were used in the test of one bridge in joint territory, the counterbalancing varied with each locomotive.

All locomotives were of the two-cylinder type, the right crank pin leading by 90 degrees. With one exception, they are all statically balanced, the J1-E engines having the main drivers cross-balanced. Of the Big Four engines, the most heavily counterbalanced is the H7-E Class, in which the hammer blow at 1 r.p.s. is 2455 lb., the amount of reciprocating parts counterbalanced being 56.4 per cent. That most favorably counterbalanced, from the Bridge Engineer's standpoint, is the H10-B, Type II, whose hammer blow is only 803 lb., 20.5 per cent of the reciprocating parts being balanced. These two classes have practically the same static effect on any span, but the dynamic effect of the former is almost three times that of the latter. The most heavily counterbalanced engine is the Erie, No. 3403, Class S-4, the hammer blow at 1 r.p.s. being 2998 lb.

No attempt is made to give any detail information as to cars, as they were too varied. The passenger cars consisted of steel coaches and Pullmans, having both 4 and 6-wheel trucks, weighing from 140,000 to 160,000 lb. Among the several thousand freight cars encountered, most every type, either foreign or Company owned, is represented, and these cars were both light and loaded.

(IV) METHODS OF TESTING AND INSTRUMENTS USED

It has been proven, by many previous tests, that the flange or bending stresses, within the elastic limit, are proportional to deflections. This, of course, does not hold good for shearing stresses, and such stresses can be obtained only by suitable instruments. Owing to induced vibrations, in the members and in the instrument itself, the mechanical type of recorder is not satisfactory for this purpose, except at very slow speeds. Stress recorders of the electric type were not available for this work, but it was felt that, if the various dynamic effects of moving loads were determined by deflections, that is, their dynamic effect in bending, a fairly close and safe estimate could be made of their effect on shear or web members. Consequently, these tests and the conclusions reached are based entirely on deflection tests.

The instruments used were designed in the office of the Chief Engineer and made in the Company's motor car shop, largely out of stock material. Two complete sets were eventually built, the construction of the second being delayed until the first could be tried out and certain details changed, as might be found necessary.

(a) Deflectometers

The general construction of the deflectometers is shown in Fig. 1. The power drum was driven by a spring motor, through a gear train, an adjustable brake being used to control its speed. The paper, on which the record was made, was four inches wide, and passed from a spool, mounted on a spindle having adjustable friction, over an idler drum, in front of which the styluses or pencils were placed, and then to the power drum. The pencil recording the deflection of the span was held in a brass sleeve, seated against a spring and operating with a nice sliding fit in an aluminum tube, which was mounted on a vertical plunger, moving in roller guides.

From the top of this plunger a spring was carried to a bracket, which was attached to the span at some point overhead. When deflections were being read directly, that is

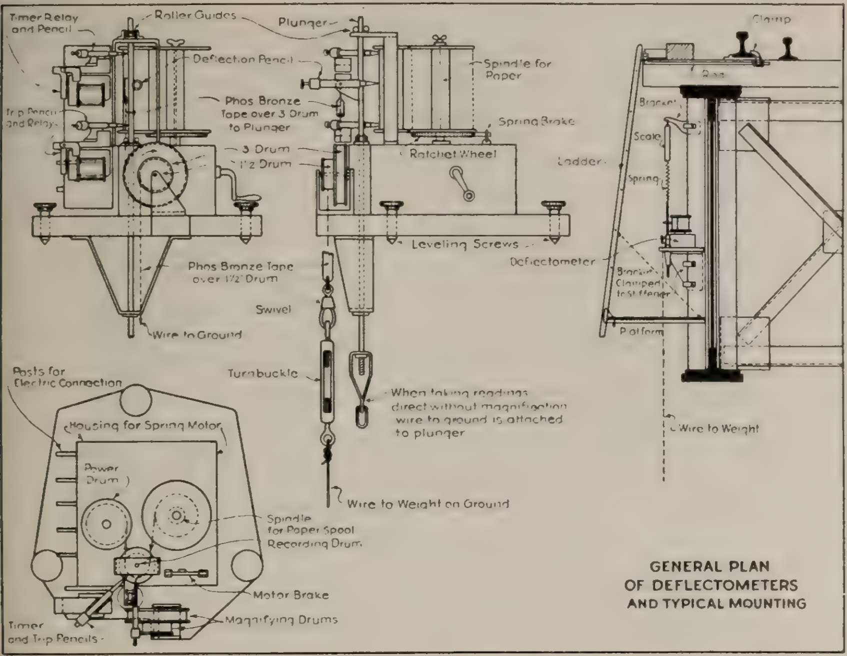

Fig. 1

unmagnified, a wire was attached to the lower end of the plunger, and through turnbuckles ran to a weight resting on the bed of the stream, or on the ground. Except on two spans, however, the actual deflections were magnified. A phosphorus bronze tape, attached to the plunger, passed over a drum 3 in. in diameter, in which was enclosed a main spring. Attached to this drum, and revolving on the same shaft, was another, 1½ in. in diameter, carrying a tape to which the wire, leading to the weight below, was connected. By this arrangement, the recorded deflections were exactly twice the actual deflections, and they could be easily measured, using a scale of 50 ft. to the inch, to .002 in.

The deflectometers were mounted on a bracket which could be clamped to the outstanding leg of a stiffener or angle of a post, or the instruments could be set directly on the top of a floorbeam or lower chord. Whenever it was possible, they were placed at the center of the span. The upper spring and the main spring in the drum kept the wire taut, and held the pencil at a fixed point in relation to the ground, just as if it had been mounted on a pole. The deflectometer moved up and down with the span, recording, at any instant, the deflection or oscillation of that point on the bridge at which the instrument was attached.

As the span moved from its initial position, there was a corresponding shortening or lengthening of the top spring. This, in turn, caused a variation in tension in the wire leading to the weight. With the small wire used, usually No. 14, even a slight change in tension changed its length somewhat, so that it was necessary to correct the scaled oscillations and deflections to account for this variation. This was done with each reading, although the correction was usually quite small, as the top spring, which was finally used, had the low constant of 0.76 lb. per inch. With a No. 14 wire 20 ft. long, the correction in the scaled deflection was about one-half of one per cent.

Mounted on the instrument were two other pencils, attached to and operated by relays. The upper one marked time intervals of ⅕ seconds; the lower indicated the position of the locomotive. With the time and position known, it was unnecessary to have a constant paper speed, and, in fact, the speed was purposely varied from time to time by means of the motor brake. To secure clear records, especially of the oscillations, it was found desirable to have higher paper speeds on short spans, and lower speeds on long spans.

The two deflectometers were used in various ways. When a single span was being tested, they would be attached to both girders or trusses, to obtain information as to rolling or swaying. On single track bridges, having spans of different length, one instrument to a span would be used. On double track bridges, one instrument would be mounted on a span in either track, where they were alike, in order to obtain as many tests as possible in any one day, and also to take advantage of the usual variation in speed, depending upon the direction of movement. During a series of tests on any one bridge, the deflectometers were freqeuntly interchanged to check any instrumental errors.

As a matter of safety as well as convenience, a specially constructed light ladder, with a working platform for the observor, was provided. It was suspended from hangers, supported on the deck, and anchored to the track rails.

Photographs of the deflectometer and typical installations, are shown in Fig. 2.

(b) Position Markers

In order to record the position and speed of the train, trips were placed along the track, being clamped against the outer face of the web of the rail. They were operated by a trigger which, when set, stood about one-half inch above the head of the rail.

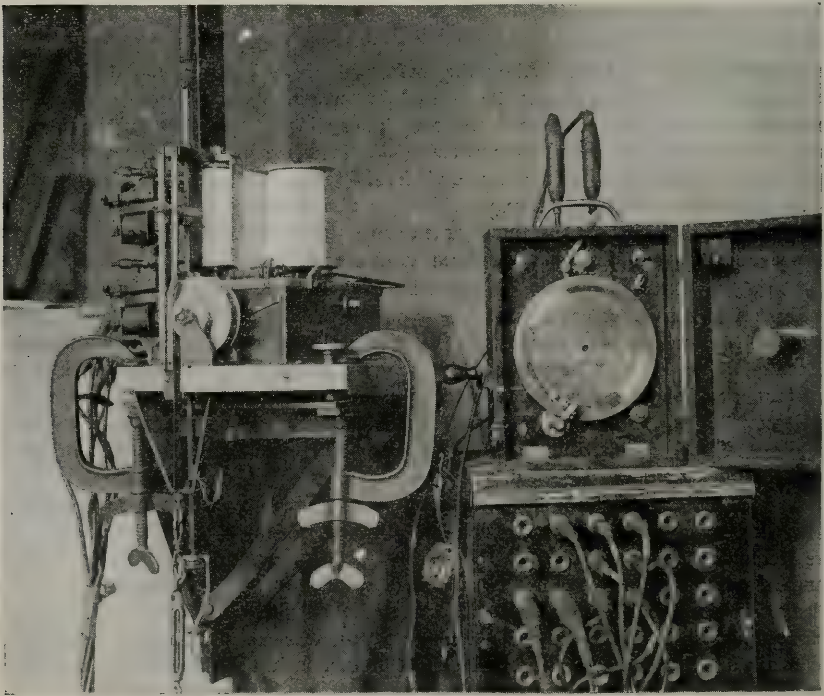

Fig. 2a. Deflectometer, Timer, Battery and Junction Box

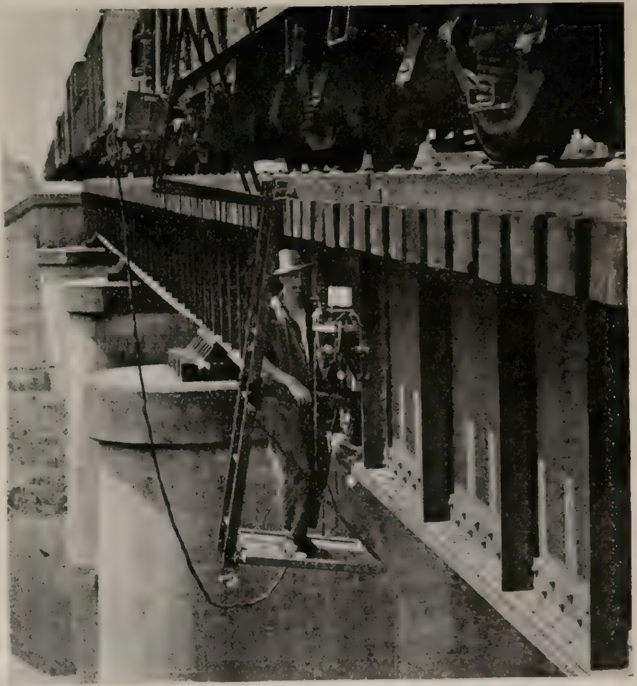

Fig. 2b. Deflectometer Installed on Deck Girder Span

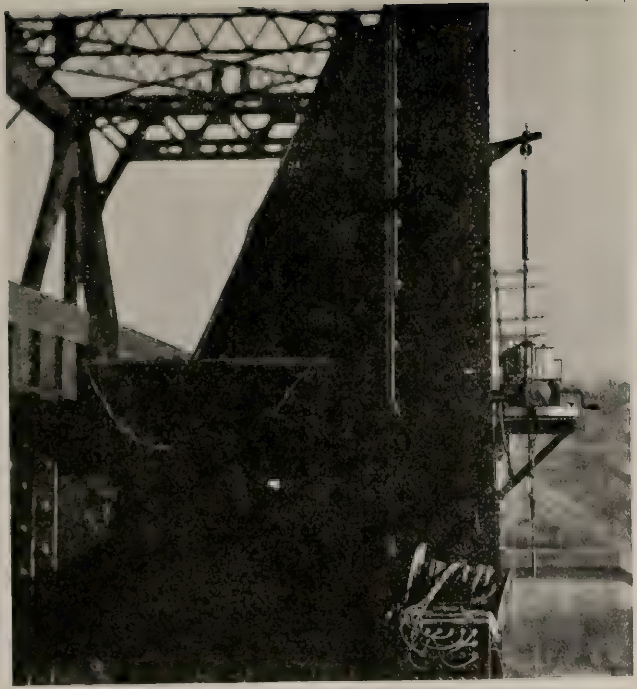

Fig. 2c. Deflectometer Installed on Through Truss Span

When the trigger was struck by the leading wheel of the engine, the circuit was instantaneously opened and closed, operating the lower relay on the deflectometer, and indicating on the record the instant each trip was struck by the leading wheel.

This seemingly simple appliance gave more trouble at first than any other portion of the apparatus. Due to the small amount of current used, it was necessary that it be practically waterproof, and the switch of such a type that it would not be operated prematurely by the vibrations set up in the track by the approaching train, especially at high speeds.

A satisfactory design was finally developed. The contact point was attached to a sliding bar operated by a spring at one end, the other end being connected by a crank shaft to a rotating disc which engaged the trigger, and, after its release, prevented the trigger arm from bouncing up above the rail until the switch was again set. The mechanism was enclosed in a tight metal box which, by means of adjustable legs, could be used on any weight or section of rail which was likely to be encountered.

The trips were held against the rail by means of short screw jacks provided with lock nuts. One end of the jack was placed in a recess in the trip housing, the other bearing against the timber guard rail of the bridge, or, for the outlying trips, against a cross timber spiked to the ends of the track ties.

It was customary to use from three to five trips for each span. Usually one would be placed at each end, directly over the bearings, and others along the track at convenient intervals. On the longer bridges, one might be placed at the center of the span, or others at intermediate points. With more than two trips, any acceleration or deceleration during the run is at once apparent, and the failure of one to operate properly, as sometimes occurred, did not invalidate the test. It was still possible to determine the average speed, at least, from any two of the trips which remained operative. The several trips were connected in series, the leads running to the battery and junction box, and then to the relay on the deflectometer.

The location of the trips used in each set of tests is shown on the span diagrams in Appendix B. Their construction is shown in Fig. 3.

(c) Timing Device

The timers were simple and accurate. They were made of discarded portable phonographs, the record tables being replaced with a brass disc, in which were 3 fiber insets, spaced 120 degrees apart. A brush, which made contact with the disc, was added, the circuit being opened each time one of the fiber blocks passed under the brush. The speed of the disc was controlled by an adjustable brake on the governor and held to 100 r.p.m., which opened the circuit 300 times per minute, or at intervals of one-fifth second. Through a relay in the battery box, the upper relay on the deflectometer was operated, marking the record every one-fifth of a second. From the spacing of these marks, at the usual paper speed, it was possible to scale to 0.01 of a second.

With this time record, and with the position marks below, the speed of the train could be accurately determined.

(d) Position of Counterweights

Inasmuch as nearly all of the trains used in these tests were regular runs, it was impossible to attach any marker to the driving wheel, which would indicate the position of the counterweight, at some particular instant, as the engine passed over the bridge.

At first this information seemed desirable, and during the first season a photograph was taken as the locomotive passed a mark, at some known distance from the end of

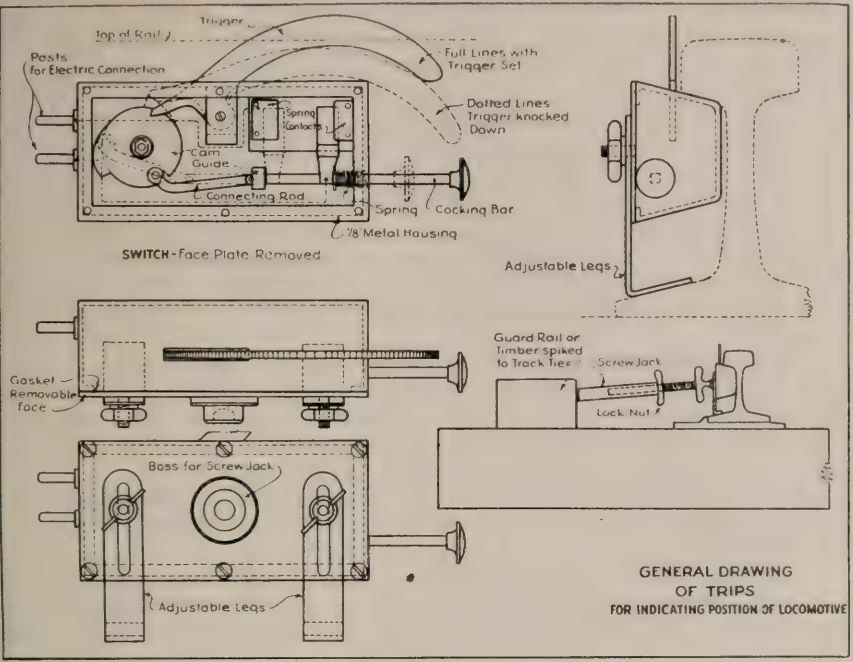
Trigger
Top of Rail
Posts for Electric Connection
Full Lines with Trigger Set
Spring Contacts
Dotted Lines Trigger knocked Down
Cam Guide
Connecting Rod
Spring
Cocking Bar
1/8" Metal Housing
SWITCH - Face Plate Removed
Adjustable Legs
Gasket Removable Face
Guard Rail or Timber spiked to Track Ties
Screw Jack
Lock Nut
Boss for Screw Jack
Adjustable Legs
GENERAL DRAWING OF TRIPS FOR INDICATING POSITION OF LOCOMOTIVE

Fig. 3

the span. By scaling the angular position of the counterweight at that point it was usually possible to find, with considerable accuracy, its angular position at any other point or at any other time. For a complete theoretical analysis of some one run such information is useful, but when we are merely interested in finding the maximum oscillation which occurred during that run, it is not necessary, and in the later tests no attempt was made to record the position of the counterweights.

(e) Information Obtained in the Field

Complete plans of each structure were in the Company's files, and it was only necessary to obtain a small amount of field data as to the bridge itself. This included the condition of the bearings, and the location of the track in reference to the center line of the span.

Notes were made as to deck construction, size and spacing of ties, weight of rail, and particularly as to the condition of the rail joints, a sketch being made to show their location.

As each train passed, one of the party observed the direction, time, engine number, and number of cars. These data were later supplemented by information obtained from the train sheets, the conductor's record as to gross weight, initial and number of cars, particularly those immediately following the locomotive, and from the coaling reports.

Each deflection record was given a serial number, those bearing the prefix "A" being taken by the A deflectometer, and those marked "B", by the B deflectometer.

(f) Analysis of Field Records

When the records reached the office, there was much work to be done on them. First a base line, representing zero live load deflection, was drawn. From the time and position markings, the time, in seconds, and distance, in feet, per inch of paper were determined. The train speed, in feet per second, miles per hour, and revolutions per second, was computed, and entered in a table stamped on the record. Light dotted lines were then drawn through the peaks of the oscillations, making fair curves. Another line, midway between these two, was added, this latter line representing the live load crawl deflection. In many cases the theoretical crawl deflection was computed, with the pilot at the ¼, ½, and ¾ points, or at other intermediate points. Where the actual live load was known, and there was no rolling or lurching of the train, the theoretical and measured crawl deflections checked closely. It is perhaps not out of place to remind the reader that these deflectometer records are nothing more than influence diagrams. As the train moves over the bridge, they record the successive changes in deflection, or oscillation, of that particular point on the span, usually the center, at which the instrument was placed.

The maximum crawl deflection, which is the static live load deflection, was then scaled, the readings being corrected for wire elongation caused by the variation in spring tension. The distance, traveled by the pilot, from the approach end of the span to its position when maximum static deflection occurred, was noted. This distance is designated as *P* in the tables of test data, which will be found in Appendix B.

Having the true deflection under some known loading, the deflection for any other load, such as the dead load, could be found, as well as the deflection factor of the span, that is, the ratio of the actual to the theoretical deflection.

As several classes of engines, with fully and partially loaded tenders, were used in the tests on many of the bridges, an opportunity was had to compare the actual and theoretical deflections under several conditions of loading, both light and heavy. This afforded a much better check on the deflection factor than if only one loading had been used, making it possible to compute, with accuracy, the deflection due to the dead load, and to the hammer blow of the locomotive, when considered as acting statically.

Much time was expended in arriving at accurate deflection factors. Later on, when we get into the theory of oscillations, we will find ourselves continually dealing with the natural frequencies of the span. But the frequency of a span depends almost wholly upon its stiffness or its deflection, and for this reason we must have, when deflections or frequencies cannot be actually measured, some reliable means of estimating them.

Mention has been made of the lines, passing through the tips of the oscillations, which were drawn on the records. They were useful in laying out the crawl deflection, but they served another important purpose, as they represent, very closely, the probable maximum oscillation of the span at any instant, even though the counterweights on the drivers were not, at that particular instant, in the angular position to cause such displacement of the span from its mean position. From these lines the maximum oscillation to be expected at any selected time, such as the instant at which the maximum static deflection occurred, could be closely estimated.

At or near synchronous speed, and at lower speeds, the oscillations keep building up until they reach a maximum, which usually occurs when the drivers have passed some distance beyond the center of the span. This time of maximum oscillation may or may not coincide with the time of maximum deflection. At velocities higher than the synchronous speed, maximum oscillations always occur some time before the time of maximum deflection, or even before the drivers reach the center of the span. Before taking off the oscillations, it was necessary to select some point on the record at which to measure them. At synchronous and lower speeds, it was customary to use the maximum oscillation, even though it occurred some time before, or after, the time of maximum deflection. At faster speeds, the absolute maximum was not always used, as in

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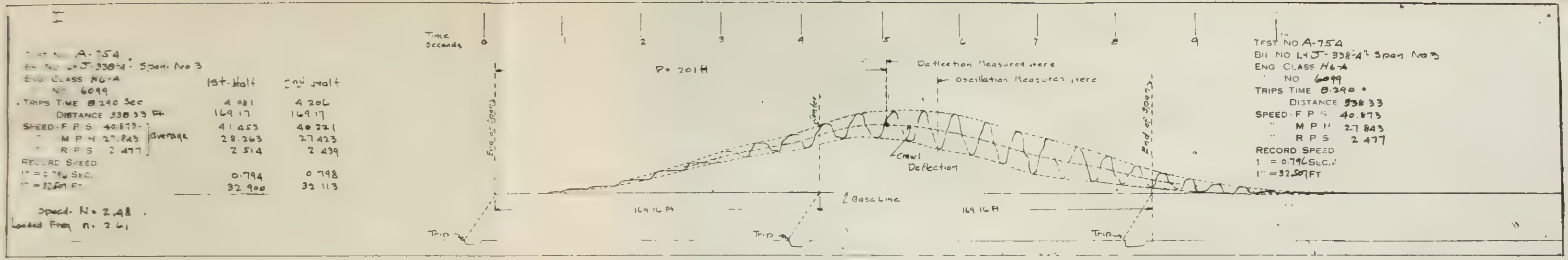
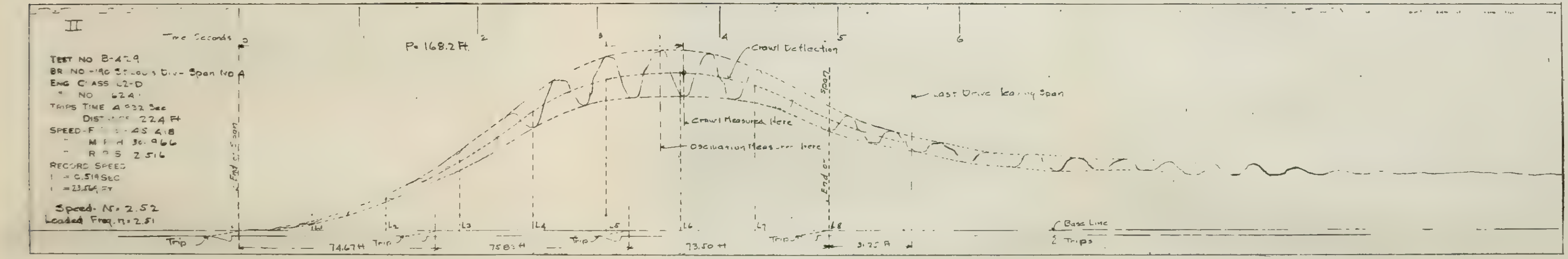
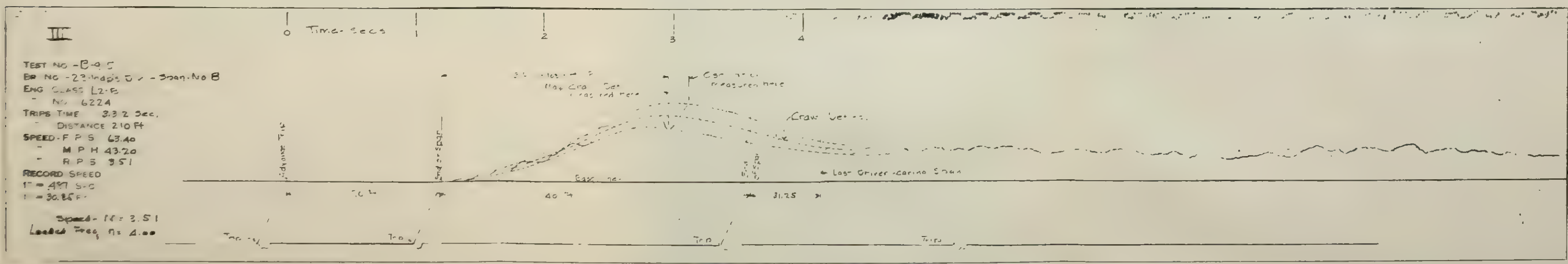


I—Deflection and Oscillations, 338 ft. 4 in. Through Truss; Span No. 3; Record A-754.



II—Deflection and Oscillations, 224 ft. Through Truss; Span No. 4; Record B-429 (See Fig. 14).



III—Deflection and Oscillations, 140 ft. Through Truss; Span No. 8; Record B-915.

FIG. 4—Deflectometer Records.

many cases, especially at speeds considerably beyond synchronism, it was so far in advance of the time of maximum deflection that it simply represented what would have occurred had the span been of a higher frequency. In such cases some point, between maximum oscillation and maximum deflection, would be taken. It is felt that this method is well on the safe side, as the magnitude of the oscillations, so taken off, are in all cases somewhat greater than those which might actually occur at the time of maximum deflection, which is, of course, the period of maximum stress.

The scaled oscillations were corrected for wire stretch, due to spring tension variation, just as was done with the deflections.

In Fig. 4, some original records are reproduced. The lines which have been added for the purpose of scaling the oscillations and crawl deflections, are shown, and the points at which the readings were scaled, are indicated.

The data taken from the field records in the manner just described are given for each span in the tables in Appendix B. To find the amount of impact for any one test we have only to divide the semi-amplitude of the oscillation by the crawl or static deflection. Until quite recently, this was regarded as the final answer to the problem and unfortunately the analysis of many tests stopped at this point. This *ratio* of oscillation to deflection in itself is really of no interest or importance, but with the aid of theory, which has at last overtaken experiment, we now have a means of putting to some real use the information obtained as to deflections and oscillations. Before taking this interesting step, however, it might be well to give some consideration to the theory upon which the process of a further analysis of the test data will be based.

(V) THEORY OF VIBRATIONS AS PERTAINING TO IMPACT IN RAILROAD BRIDGES

Anyone investigating the subject of Impact will find himself deeply indebted to Professor S. Timoshenko, of Ann Arbor, and Professor C. E. Inglis, of Cambridge. Professor Timoshenko has clearly outlined the general theory of vibrations in structures, while Professor Inglis has concentrated on the particular problem of vibrations produced in railroad bridges under the action of the steam locomotive. Others have contributed valuable suggestions, and the books and papers, to which reference has been made and which are listed in an appendix, will be of much help to anyone undertaking a study of this subject. He will find there, not only the development of the few equations and formulas which are given in this paper, but an interesting discussion of the theory of vibrations as well.

(a) Causes of Impact

The dynamic addition to the static effect of locomotives and trains, on railroad bridges, may be caused by any one, or combination, of the following:

(1) A periodic alternating force, produced by that portion of the counterweight on the locomotive drivers, which has been provided to counterbalance a portion of the reciprocating parts.
(2) Low joints or other irregularities in the track, and eccentric or rough wheels of the locomotive and cars.
(3) Smoothly rolling loads, such as electric locomotives.
(4) The vertical oscillation of that portion of the car which is carried on springs.
(5) The rolling or swaying of the locomotive and cars. While the force so produced may, under certain conditions, be periodic in nature, it can well be considered as a static force, and be provided for by an addition to the static live load.

Being elastic, every bridge span has a period of free, or natural, vibration after it is once set in motion. These vibrations are harmonic in character and, for any one span, their frequency or period depends almost wholly upon the amount of load on the span. Their frequency may be affected somewhat by damping forces, which are opposed to motion, but this effect is small, except where the amount of damping is quite large, as may be the case in stiff short spans. Or we may say that, for any one span, the period of its natural or free vibration, depends almost entirely upon its deflection, the vibrations being slower when the span is heavily loaded than when it is lightly loaded. For spans of the same length and equally loaded, that is, equally stressed, we may expect higher natural frequencies in deep, stiff spans, than in shallow, flexible spans.

When a pulsating or periodic disturbing force is applied to the bridge, forced vibrations are induced, and their frequency corresponds to that of the disturbing force. The magnitude of these forced vibrations, and the stresses which they produce, will depend upon the relation between the frequency of the disturbing force and the natural frequency of the bridge. As the period of the force approaches or becomes equal to the period of the natural vibration of the structure, its effect is magnified, and if this disturbing force were to continue for an appreciable time, and there were no opposing internal or external force, such as damping, to neutralize its effect, the oscillations would soon become very large. Fortunately, damping, in some degree, is always present and a limit to the extent of oscillations is soon reached, beyond which there is no further increase. With a fixed amount of damping, the magnitude of the forced oscillations, at any one frequency of application of the disturbing force, is directly proportional to the intensity of that force.

It is evident, from what has just been said, that before we can go very far in determining the magnitude of the forced vibrations, which is the measure of impact, we must have some method of finding the frequency of the free vibration of the span.

(b) THE FREQUENCY OF NATURAL OR FREE VIBRATIONS

If a massless spring supporting a weight which produces an elongation, e, in feet, is disturbed from its position of equilibrium, the period or time, T, in seconds, of one complete oscillation, will be $2\pi\sqrt{\frac{e}{g}}$. The frequency, n, of these vibrations, number per second, will be $n=\frac{1}{T}=\frac{1}{2\pi}\sqrt{\frac{32.2}{e}}$ Substituting for π, and expressing the elongation e, in d inches, the natural frequency of the spring is:

$$n=\sqrt{\frac{9.8}{d}} \qquad (1)$$

This same equation also defines the natural frequency of a massless beam with hinged ends, carrying a single concentrated load which produces a central deflection, of d inches.

If the beam be uniformly loaded, and the central deflection under this load is d inches, its natural frequency is:

$$n=\sqrt{\frac{12.4}{d}} \qquad (2)$$

The uniform load may consist of the weight of the span itself, or its dead load combined with a uniformly distributed live load.

For a combination of one or more concentrated loads located at any point on the beam, with a uniformly distributed load, J. N. Goodier[6] has suggested the following formula:

$$n^2 = \frac{g\,C}{4\pi^2\left[\int_o^L w\,Sin^2\frac{\pi x}{L}dx + \Sigma\,R\cdot Sin^2\frac{\pi a}{L}\right]} = \frac{g\,C}{4\pi^2\left[\frac{w\,L}{2} + \Sigma\cdot R\cdot Sin^2\frac{\pi a}{L}\right]}. \quad (3)$$

In which:

$C =$ the central concentrated load, required to produce unit (*1* foot) deflection.
$w =$ the uniformly distributed load per foot on the beam, either dead or live.
R_1, R_2, R_3, etc. $=$ the concentrated loads on the beam.
a_1, a_2, a_3, etc. $=$ the distance of the loads R_1, R_2, R_3, etc., from one end.
$L =$ length of span.

With a massless beam, $\frac{w\,L}{2} = 0$, and assuming a single load R, at the center, $\Sigma R\,.\,Sin^2\frac{\pi a}{L} = R$. Using deflection, in inches, $C = \frac{48EI\,12}{L^3}$ and $R = \frac{48EId}{L^3}$. Substituting these values in equation (3), $n = \sqrt{\frac{9.8}{d}}$, which is the same as equation (1). Assuming a uniform load only, that is $R = 0$, and writing $\frac{w\,L}{2} = \frac{38.4EId}{L^3}$, equation (3) then becomes, $n = \sqrt{\frac{12.4}{d}}$, which is equation (2).

With these three formulas, the natural frequency of any span, under any condition of loading, can be closely estimated when its deflection or stiffness is known. For spans of about 100 ft. or over, the concentrated, or axle, loads can be reduced to an equivalent uniform load, and formula (2) be used. On shorter spans, where the distance between axles is appreciable as compared with the span length, formula (3) should be used.

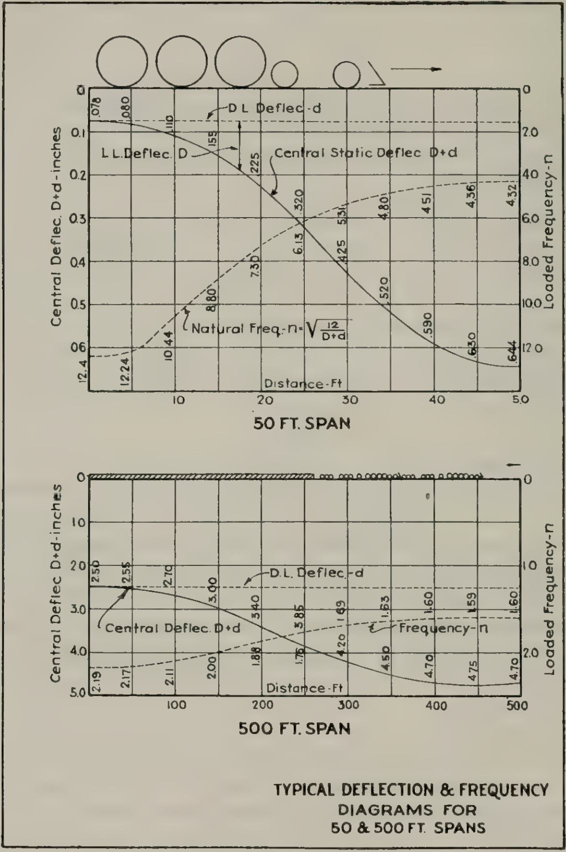
It has already been mentioned that the frequency of the natural vibration is affected slightly by the damping forces. Although this will be taken up later on when we consider the subject of damping, it may be stated here that the damped frequency,

$$n^1 = \sqrt{n^2 - \delta^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

In which n is the undamped frequency, and δ is the damping coefficient of the span. This reduction is insignificant except in short spans in which the amount of damping is large. It is unnecessary to make this correction when calculating frequencies for the purpose of estimating impact, but it is desirable to do so when analyzing impact tests.

Inasmuch as the frequency of the span, for any loading, is a function of its deflection, it is apparent that as the train moves over the span, its frequency must constantly change, since the central deflection changes with every position of the load. On a short span, this variation in frequency is quite rapid, as the dead load deflection is small, and its unloaded frequency may be two or three times its loaded frequency. On long spans, in which the weight of the span itself is large, the difference between the unloaded and loaded frequencies is small, so that the span may have practically the same frequency during the time the train is passing over the greater portion of its length. This is illustrated in Fig. 5.

The upper diagram is typical of a 50 ft. girder, having a span-depth ratio of 12, the assumed live load being such as to produce a total unit stress of about 18,000 lb. The crawl deflection line represents the central deflection, due to both the dead and live load, for each successive position of the engine as it moves across the bridge, and the frequency line shows the variation in frequency, corresponding to the changing load or deflection. The unloaded frequency of the span is 12.4, but when the pilot wheel has reached the center of the span, its frequency has decreased to 6.13. When it has traveled 10 ft. further, the frequency is only 4.8, and when it reaches the end of the span, the deflection has just about reached its maximum, and the frequency is 4.3.



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If the locomotive were running at a speed of 7 r.p.s., it would be within 10 per cent of synchronism between the frequencies of 6.3 and 7.7. This could only occur while the pilot wheel was between 18 and 24 ft. from the approach end, or during a travel of 6 ft., which at this speed would be, in time, something like .05 of a second. If the engine were running at synchronous speed, that is, 4.32 r.p.s., it would be within 10 per cent of synchronism while it was traveling the last 15 ft. Had this been a deep girder, with a span-depth ratio of 6, and loaded in the same manner, the unloaded and loaded frequencies would have had the respective values of about 17.4 and 5.8. On such short spans it is quite evident that if synchronism does occur, it is of such short duration that but little magnification of the effect of the disturbing force can take place.

The lower diagram gives the crawl deflection and corresponding frequency curve for a 500 ft. span. In this case the dead load is about equal to the live load, and the unloaded and loaded frequencies are within the rather narrow range of 2.2 to 1.6. On such a bridge the disturbing force may be at or near synchronous speed for a considerable period of time, with a consequent large magnification of its effect. But the disturbing force, which in the case of a locomotive is its hammer blow, is small, as it varies with the square of the speed, and at 1.6 r.p.s. on the 500 ft. span, it is only 1/7 of what it would be at 4.3 r.p.s., or about 1/20 at 7 r.p.s., on the 50 ft. span.

(c) DEFLECTIONS

In estimating the amount of impact on any span it is necessary to know its natural loaded frequency, and inasmuch as its frequency, under any condition of loading, depends almost wholly upon its deflection, it is important that we have some means of determining the amount of deflection under the particular loading being considered. When the deflection has been measured under some known load, it is possible to make a close approximation of the deflection under any other loading. When no measured deflections are available, estimated deflections must be used, in which case we require some definite information as to the deflection factor of the bridge. The methods, which have been found most convenient, will be given.

(1) Deck Girder Bridges

For a beam of uniform cross-section and Moment of Inertia, having a length L, and carrying a load R, distant a, from one end, the deflection y, at any point x, can be expressed by the series:

$$y_x = \frac{2\,R\,L^3}{\pi^4\,EI}\left[Sin\,\frac{\pi a}{L}\cdot Sin\,\frac{\pi x}{L} + \frac{1}{2^4}\cdot Sin\,\frac{2\,\pi a}{L}\cdot Sin\,\frac{2\,\pi x}{L} + \ldots \right] \ldots\ldots\ldots (5)$$

For all practical purposes, only the first harmonic need be considered, and the deflection y_x, becomes:

$$y_x = \frac{R\,L^3}{48\,EI}\cdot Sin\,\frac{\pi a}{L}\cdot Sin\,\frac{\pi x}{L}, \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

and the central deflection, y, produced by any number of concentrated loads, R_1, R_2, R_3, etc., at distances a_1, a_2, a_3, etc. from one end, is:

$$y = D = \frac{L^3}{48\,EI}\cdot \Sigma\, R_1\,.\,Sin\,\frac{}{L} + R_2\,.\,Sin\,\frac{\pi a_2}{L} + \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

In the same way, it can be shown that, for a uniform load of w lb. per ft., the central deflection is:

$$y = d = \frac{L^3}{48\,EI}\cdot\frac{w\,L}{1.6} \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

It will be seen at once that the term $\Sigma\, R\,.\,Sin\,\frac{\pi a}{L}$, of equation (7), represents the equivalent central load, which will produce the same central deflection, as the several concentrations R_1, R_2, R_3, etc., and that the term, $\frac{w\,L}{1.6}$, of equation (8), is the equivalent central load, which will produce the same central deflection, as a uniformly distributed load of w lb. per ft.

Or, if we are considering the deflections caused by hammer blows of Q_1, Q_2, Q_3, etc. for the various wheels of the locomotive, the central deflection is:

$$y = D_h = \frac{L^3}{48\,EI}\Sigma\, Q\,.\,Sin\,\frac{\pi a}{L} \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Having the live load deflection, *D*, under some locomotive or train, of which the axle or wheel loads, *R*, and the wheel locations, *a*, are known, the dead load deflection, *d*, due to the weight of *w* pounds per foot, can be found from equations (7) and (8), or:

$$\frac{d}{D} = \frac{w\,L}{1.6 \sum R\,.\,Sin\,\frac{\pi a}{L}} \,, \quad \ldots\ldots \quad (10)$$

and the hammer blow deflection may be similarly obtained from the measured live load deflection, *D*, by the ratio:

$$\frac{D_h}{D} = \frac{\sum Q\,.\,Sin\,\frac{\pi a}{L}}{\sum R\,.\,Sin\,\frac{\pi a}{L}} \quad \ldots\ldots \quad (11)$$

When we have to estimate the deflection of a girder, on which no measured deflections are available, it is necessary to use the M. of I., corrected by the deflection factor, and take into account the shear, as well as bending, deflection. The usual deflection formulas assume the beam to have a uniform M. of I. throughout its length, but in the built up girder, only *50* to *80* per cent of its section may be continued throughout its length. For all spans tested, the theoretical deflection, D^1, under one or more conditions of test loading, was computed from equation (6), using the Gross M. of I. at the center for bending, and adding the deflection due to shear. The ratio of the actual measured deflection *D*, to the theoretical deflection D^1, that is $\frac{D}{D^1}$, is called the *deflection factor.*

As will be seen in Table V, Part VI, these factors for all spans, both shallow and deep, are quite constant.

Having the deflection factor, we can convert the Gross M. of I., as taken at the center, to an *Equivalent Uniform M. of I.*, which can be used in the usual deflection formula. For example, if the gross central M. of I., of a girder span, is 200,000, and its deflection factor was found to be 1.08, its equivalent uniform M. of I. would be, $\frac{200{,}000}{1.08} = 187{,}200$. To the calculated deflection, due to bending, the shear deflection must be added, especially when dealing with deep girders, as in such spans the shear deflection may amount to 10, or even 25, per cent in very deep girders, of that due to bending.

(2) Truss Spans

The most convenient method of estimating deflections in trusses is to first compute the contribution made to the central deflection by a unit load at each panel point, and take the sum of the panel point coefficients multiplied by the actual panel load. This was done for all spans, using the gross section of the members, and their full length, from center to center of intersections for riveted trusses, and center to center of pins for pin connected trusses. The deflection factor, for all truss spans tested, was found in the same manner as for deck girders, that is, by taking the ratio of some measured deflection, to the calculated theoretical deflection for that load. For through spans, in which there were no slack eye-bars, and little pin wear, this factor varied only from 0.79 to 0.84, as shown in Table IV, Part VI.

Whether the trusses were riveted or pin connected seemed to have no influence on the value of this factor, so that apparently the stiffness of the connections has but little, if any, effect on deflection. In Span No. 11, a 122 ft., 3 in., pin connected through truss, there were several slack eye-bars at the time it was tested, but this condition was later corrected, after which strain gage readings were taken under the slow movement of an engine of known weight, and the ratios of the measured to the theoretical stress were found to be as follows:

Top chords	100.00
Posts	103.00
Hip verticals	112.00
Diagonals	103.00
Lower chords	63.00

The calculated deflection, using these measured stresses, gives a deflection factor of .816, which is not far out of line. Practically all members, except the bottom chords, were taking their full stress. These were undoubtedly being relieved by the floor system, and it is this condition which makes for deflection factors of less than unity.

(3) Through Girders

No through girder spans were tested, but it is probable that the floor system, if it consisted of stringers framed in between floor beams, would take part of the lower flange stress just as was found in trusses. The deflection factors would probably fall between those for through trusses and deck girders, and it is suggested that, until more information is available, a deflection factor of 0.95 be used for estimating the deflection of such structures.

(4) Deck Girders With Solid Floors

Eight spans with concrete decks were tested. On each bridge, the deck had been poured in place, and while no bond, between the slab and girder flange, had been intentionally provided, the rivet heads and friction seem to offer sufficient resistance to shear in this plane, as in each case the deck acted as flange section, resulting in small deflections. The factors, as determined for these spans, are reasonably consistent and will be found in Table VI. They are given for the combined section and for the section of the steel only. Usually, the deck is of about the same section, regardless of the span length, so that it would be better to use the M. of I. of the composite section, in computing the deflections of spans on which the deck is acting as part of the girder. When the supporting girders are not symmetrically placed about the center of the track, as is frequently the case when more than two girders are used in the group, it is necessary to consider the torsional deflection due to eccentricity.

Although no tests were made with girders on which the floor consisted of timber or precast slabs, the deflection factors of spans of this type, based on the section of steel only, should not differ greatly from those found for open deck spans, although they might be somewhat lower.

(d) DAMPING

If there were not some opposing force, that is damping, the forced vibrations in many structures would soon build up to dangerous proportions, especially when synchronism occurred. But damping forces, of one kind or another and of various intensities, are always present, and in railroad bridges, at least two or more are quite likely to be acting simultaneously.

We have some idea as to their combined effect, but as yet possess very little knowledge of the exact effect of each, when considered separately. These opposing forces may result from:

(1) *Damping due to the elastic friction of the material in the bridge itself.* This may be called elastic damping, and in any particular span, it becomes smaller with an

increase in the load and, generally speaking, it may be said that such damping is much less on long and shallow, heavily loaded spans, than on short and stiff, lightly loaded spans. Damping of this form is proportional to velocity, and consequently it is a function of the natural frequency of the structure.

(2) *Damping due to external friction, such as is found in the end bearings.* This may be either sliding friction, where flat bearing plates are used, or rolling friction, if the bridge is provided with expansion rollers. For one condition of loading this damping is constant and, unlike elastic damping, it increases with an increase in load. But even with the same intensity of load, the amount of friction will depend upon the condition of the bearings. If they are dirty or badly corroded, the friction, and consequently the amount of damping, will be greater than if they were in good condition.

(3) *Damping due to the load itself.* The greater portion of the locomotive and car weights are spring borne. When the vibrations in the structure are of such magnitude and rapidity that the acceleration of the sprung mass will produce a force great enough to overcome spring friction, the sprung weight is set in motion and the spring friction then becomes an active force opposing the growth of the vibrations.

(4) It is quite probable that a portion of the energy input is sometimes absorbed by the bridge substructure, especially if the piers are tall and slender. In many such structures there is a noticeable movement of the piers, and a mass of such proportions cannot be set in motion without consuming energy.

(5) To the above causes of damping might be added the cushioning effect of the deck, especially if it consist of a solid floor carrying a ballasted track.

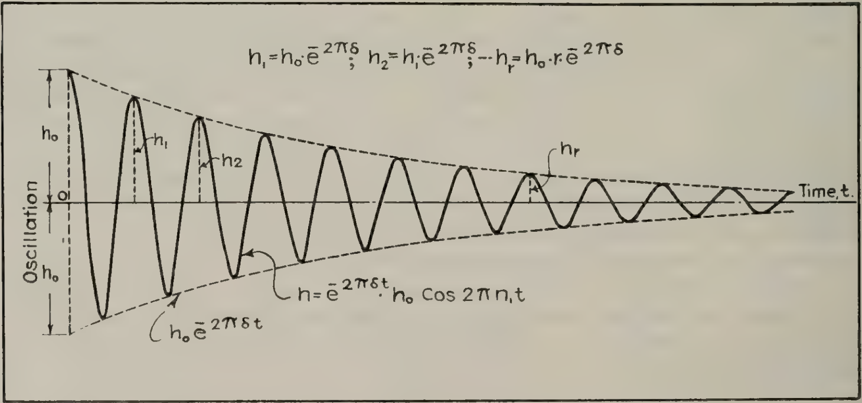


Fig. 6. The Effect of Damping Proportional to Velocity

Damping of type (1), that due to elastic friction, and type (2), that due to external friction, are found acting together in every bridge, one becoming smaller as the other becomes larger, with an increase or decrease in the load. On spans of certain lengths there may be combined with these two the damping caused by friction of the springs on the locomotives or cars. If the deck structure does contribute anything in the way of damping, it is always acting with types (1) and (2). The fourth type, that due to the movement of the substructure, may be present only in certain structures.

Damping due to elastic or internal friction, being proportion to velocity, has the effect of reducing the oscillations in geometrical progression. In his studies, Professor

Inglis[9, 10] has considered this form of damping as a distributed opposing force per unit length of span, as expressed by the term, $4\pi\delta\frac{w}{g} \cdot \frac{dy}{dt}$, in which δ is the damping coefficient, and $\frac{w}{g}$ the mass of the span per unit length. The rate at which the vibrations die out is defined by the expression, $e^{-2\pi\delta t}$ Assuming δ to have a value of .0355, the rate becomes 0.8, and the oscillations subside as shown in Fig. 6.

In a bridge with frictionless bearings, the free oscillations should die out in some such manner. If we could record them, and measure the height of the successive oscillations, the damping coefficient, δ, could be determined. With the addition of a constant damping, due to end bearing friction which exists in every bridge, they would subside more rapidly. In actual tests of bridges with locomotives, these residual vibrations are not often found and when present they are too small for any accurate determination of the damping coefficient. The Bridge Stress Committee[4] made use of a stationary oscillator to set the bridge in motion, and the values of the damping coefficients, for the unloaded spans, given in that report were presumably obtained by that means. However, the spans which it tested were much shallower, and had much lower natural frequencies than those ordinarily met with in this country, so that we cannot adopt, without question, the coefficients given in its Report.[4]

As has been previously stated, the damping coefficient, δ, becomes smaller as the load on the span increases. If δ_1 is the coefficient when the span is carrying a load of w_1 pounds per ft., and δ_2 is the coefficient corresponding to a load of w_2, $\frac{\delta_1}{\delta_2} = \frac{w_2}{w_1}$. Where d_1 and d_2, are the central deflections, due to the loads w_1 and w_2, $\frac{\delta_1}{\delta_2} = \frac{d_2}{d_1}$. From equation (2), (pg. 22), $n_1^2 = \frac{12.4}{d_1}$, and $n_2^2 = \frac{12.4}{d_2}$, so we may say that:

$$\frac{\delta_1}{n_1^2} = \frac{\delta_2}{n_2^2} = \frac{\delta_3}{n_3^2} = \text{etc.} = p, \text{ a constant} \ldots\ldots \quad (12)$$

It is evident that p, which will be called the *damping constant,* remains unchanged for any span, regardless of the amount of load it carries. And if p is found experimentally under some loading, which results in a natural frequency of n_r, the damping coefficient δ_r, corresponding to that loading or frequency can be found from the equation:

$$\delta_r = p\, n_r^2 \ldots\ldots \quad (13)$$

It is this form of damping which affects the frequency, n, of the vibrations, as stated on page 23, but the effect is small for most spans, as shown by equation (4), $n^1 = \sqrt{n^2 - \delta^2}$, which has been derived by Professor Timoshenko,[7] and Professor Inglis.[9] Assuming the damping constant, p, to have a value of .03, and that the undamped natural frequency of the span, n, is 5.0, the damping coefficient, $\delta = p\, n^2 = 0.75$, and the damped frequency, $n^1 = 4.93$. On shorter or stiffer spans, the difference is greater. In estimating the amount of impact for any span, it is on the safe side to ignore this correction, as the higher frequency will give a larger impact, but this adjustment is necessary in an analysis of tests.

From end bearing friction, we have a form of damping which is constant under any one condition of loading and, unlike elastic friction, it becomes larger with an increase in load on the span. Damping of this type causes a reduction in magnitude of the oscillation in arithmetrical progression, that is, each oscillation is less, than the preceding one, by a constant amount, as shown in Fig. 7. This form of damping has no effect on the frequency of the vibrations.

In most bridges it is, no doubt, the combination of these two damping forces which has the greatest effect on checking and holding within reasonable limits the vibrations set up by the hammer blow of the locomotive, or any other periodic disturbing force On long heavily loaded spans, damping due to end bearing friction probably predominates, as in such structures, which always have low natural frequencies, the damping due to elastic friction is small. In short spans the opposite is probably true; here the end friction is small as the load is comparatively light, and as the natural frequencies of such bridges are high, the damping due to internal friction will be large.

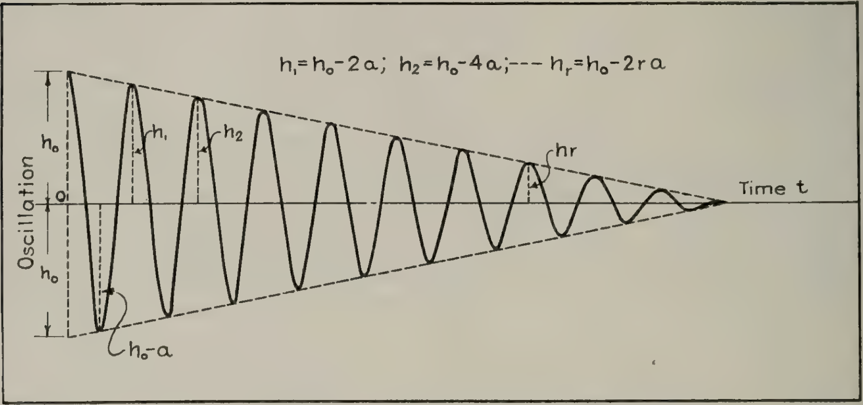


Fig. 7. The Effect of a Constant Damping on Vibrations

The third important form of damping, that due to friction of the locomotive springs, after the sprung mass has once been set in motion, is found only in spans of certain lengths and frequencies, so that it will be discussed when we examine the effect of the locomotive on such spans.

(e) Impact from the Steam Locomotive

Having considered two of the factors—frequency of vibration and damping—which play such an important part in determining the amount of impact on bridge spans, we are in a better position to investigate the dynamic effect of the various external forces producing impact.

The greatest single cause of impact, except perhaps in very long spans, is the effect of the two-cylinder steam locomotive. In this case the periodic disturbing force, which for a better term will be called the *hammer blow,* is due to the centrifugal force of the overbalance on the revolving drivers. This overbalance, or excess counterweight, is that portion of the counterweight which is added to counterbalance some portion of the inertia force produced by the reciprocating parts, such as the piston, piston rod, crosshead, etc. This disturbing force, at any instant, t, during the passage of the locomotive drivers across the span, is $Q\,N^2\,Sin\,2\pi\,N\,t$, in which Q is the centrifugal force, in pounds, of the overbalance when the drivers are revolving at 1 r.p.s., and N is the speed of the locomotive expressed in r.p.s. The maximum intensity of the force occurs when $Sin\,2\pi\,N\,t = \pm 1$, at which time, the force is $\pm\,Q\,N^2$. This force may be taken separately for each driving wheel, or each pair of wheels on one axle, or as a single force, equivalent in effect to the sum of the distributed forces.

As partial or complete synchronism occurs, that is when N, the speed of the locomotive, expressed in terms of revolutions of the drivers per second, approaches or equals the natural frequency, n, of the bridge, magnification of the effect of the force, $Q N^2$, takes place, with a corresponding increase in the forced vibrations. The ratio of the semi-amplitude of these magnified oscillations to the deflection of the span, due to the force $Q N^2$, when considered as acting *statically at the center,* has been designated, in the Report of the Bridge Stress Committee,[4] as the *dynamic magnifier.* If D_h is the central deflection of the span, due to the force Q (the hammer blow at 1 r.p.s.) acting statically at the center and k is the dynamic magnifier, the semi-amplitude, h, of the magnified oscillations, produced by the force $Q N^2$, is:

$$h = k D_h N^2, \quad \ldots\ldots \quad (14)$$

or:

$$k = \frac{h}{D_h N^2} \quad \ldots\ldots \quad (14a)$$

If D is the central static deflection due to the live load on the bridge, the impact is $\frac{h}{D}$, or:

$$\text{Impact} = k \; \frac{D_h \; N^2}{D} \quad \ldots\ldots \quad (15)$$

By this simple formula it is possible to determine, for any span, the amount of impact caused by a locomotive, having a hammer blow of Q lb. and running at a speed of N, r.p.s., as soon as we have a means of arriving at the proper value of k, the dynamic magnifier. All other terms are known, or can be easily obtained. It is only necessary to have the weight and wheel spacing of the load, the counterbalance report of the locomotive, and the deflection factor of the span. The value of k depends largely upon the type of bridge being considered and, when being investigated for impact, the spans may be divided into three groups

(1) The Impact from the Locomotive on Short Spans

Short spans have natural frequencies so high that synchronism cannot occur, owing to the impossibility of attaining a locomotive speed of much over 7 r.p.s., and when synchronism does occur, it is of such short duration, see Fig. 5, that very little if any magnification can take place. On very short spans, k is unity, or a little less, and the impact, from equation (15), is simply $\frac{D_h \; N^2}{D}$; or the ratio of the deflection, due to the hammer blow considered as acting statically, to the static live load deflection. The amount of impact is directly proportional to the square of the speed, and to the intensity of the hammer blow, or amount of excess counterweight on the drivers. It is inversely proportional to the static deflection, or to the amount of live load on the bridge.

On spans over 20 or 30 ft. in length, depending upon their loaded frequency, some magnification may occur, and such spans may be treated in the same manner as those of intermediate length, on which the locomotive springs remain locked.

(2) Impact from the Locomotive on Spans of Intermediate Length

For convenience, this group will include those spans whose natural loaded frequencies are within the range of possible engine speeds, and which oscillate in such a manner as to overcome the friction in the locomotive springs. Shallow spans of 30 to 40 ft. in length, when heavily loaded, may have a period of vibration of such frequency that synchronism may occur, but the oscillations, although comparatively rapid, are not large enough to overcome spring friction. Such spans will be considered under Case I. Spring action may occur however in spans from 40 to 175 ft. in length, and we have an entirely different condition as to damping and frequencies, which will be designated as Case II.

Spans of intermediate length then, will embrace those having lengths of approximately 40 to 175 ft. Between span lengths of about 100 to 125 ft., we encounter two different types. If they are girder bridges, they must necessarily be comparatively shallow and flexible, having low frequencies, but if they are through truss bridges, they will be quite deep and stiff, and their natural frequencies will be much higher. While the method of dealing with each type is identical, we may expect to find more impact in one than in the other, although subjected to the same hammer blow, and loaded to produce the same intensity of stress.

Professor Inglis[9, 10] has suggested an approximate method of dealing with the spans in this group. For the moving locomotive, with distributed wheel loads and hammer blows, he substitutes an equivalent weight and force, concentrated on a single wheel; and assumes that this wheel rotates for an indefinite period of time, without moving forward. This assumption is justified on the theory that, on such spans, the amount of damping, either from the bridge itself or from the locomotive springs, is so large, that the forced vibrations build up to their maximum in a very short time. Having reached this maximum, they are not affected by the continued application of the counterweight force.

This method seems to be accurate enough for all practical purposes. When the actual tests are compared with the theoretical values of the oscillations, the agreement is remarkably close as will be seen in Appendix B.

Letting

$N =$ the frequency of the hammer blow, r.p.s.
$n_s =$ the natural frequency of the locomotive springs.
$n_1 =$ the natural frequency of the span, times per second, when loaded with the train, tender, and unsprung weight of the locomotive.
$n =$ the natural frequency of the span, when loaded with the train, tender, and entire locomotive.
$n_o =$ the natural frequency of the unloaded span.
$\Theta =$ the damping coefficient of the locomotive springs.
$\delta_o =$ the damping coefficient of the unloaded bridge.
$d =$ the deflection at the center, under the dead load of w pounds per foot.
$D =$ the deflection at the center, under the live load.
$D_h =$ the deflection under the hammer blow, at 1 r.p.s., when considered as acting statically at the center of the span.
$\beta = \frac{D_h}{D}$, the ratio of hammer blow to the live load deflections.
$h =$ the semi-amplitude of the oscillations, measured at the center.

Professor Inglis[9] has derived the following equations for the dynamic magnifier:

$$k = \sqrt{\frac{(N^2 - n_s^2)^2 + (2N\Theta)^2}{\phi^2 + \psi^2}} \quad \text{(16)}$$

in which

$$\phi = \frac{N^4}{n_1^2} - N^2\left[1 + \frac{4\delta_o \Theta}{n_o^2} + \frac{n_s^2}{n^2}\right] + n_s^2 \quad \text{(16a)}$$

and

$$\psi = 2N\left[\Theta \frac{n^2 - N^2}{n^2} + \frac{\delta_o}{n_o^2}\left(n_s^2 - N^2\right)\right] \quad \text{(16b)}$$

Spans of Intermediate Length

CASE I. LOCOMOTIVE SPRINGS INACTIVE

Considering first, Case I, which assumes that the vibrations are neither large enough nor rapid enough to overcome the friction of the locomotive springs, so that they remain locked and inactive, that is, the entire locomotive acts as a unit, and there is no independent oscillation of its sprung weight. Under this condition, $n_1 = n$; θ and $n_s = 0$, and the expression for the dynamic magnifier becomes:

$$k = \frac{1}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(\frac{2\delta_o N}{n_o^2}\right)^2}} \quad \text{(17)}$$

If δ_o represents the damping coefficient of the unloaded bridge, which has a natural frequency of n_o, we can substitute for $\frac{\delta_o}{n_o^2}$, the damping constant of the span, p, (see equation 12), and the second term under the radical becomes, $\left(\frac{2\delta_o\ N}{n_o^2}\right)^2 = (2p\,N)^2$ $= \left(2p\,n\,\frac{N}{n}\right)^2$. If we define the term $2pn$, as the *damping factor*, Δ, then:

$$\Delta = 2p\,n = \frac{2\delta}{n} \quad \text{(18)}$$

This is the expression for the damping factor of the span, under the particular loading which results in the span having a natural frequency of n. Since p is a constant, it will be seen that the damping factor, Δ, becomes smaller as the load on the span increases, that is, as its natural frequency becomes lower.

Substituting in equation (17), we get for the dynamic magnifier:

$$k = \frac{1}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(\Delta\ \frac{N}{n}\right)^2}} \quad \text{(19)}$$

It is interesting to note that Professor Timoshenko[7, 8] obtained this same equation in considering the case of a coil spring having a natural frequency of n, and subjected to a periodic disturbing force acting N times per second, the amount of damping present being represented by Δ.

From equation (19), it is apparent that the degree of magnification of the oscillations depends upon the relative frequencies of the operating force and the span, or $\frac{N}{n}$, and the amount of damping present. When there is no damping, k becomes infinite at synchronous speed ($N = n$). With damping, at synchronism,

$$k = \frac{1}{\Delta} = \frac{1}{2p\,n} \quad \text{(20)}$$

and the semi-amplitude of the oscillation becomes (see equation (14)),

$$h = k\,.\,D_h\,N^2 = \frac{D_h\,n}{2p} \quad \text{(21)}$$

Since D is the static live load deflection, and $\beta = \frac{D_h}{D}$, the impact, at synchronous speed, from equations (15) and (21), is:

$$\text{Impact} = \frac{h}{D} = \frac{D_h\,N^2}{D\,.\,2p\,n} = \frac{\beta\,n}{2p} \quad \text{(22)}$$

This is the complete expression for the maximum amount of impact to be expected on any span in this group, resulting from the hammer blow of the locomotive, when running at synchronous speed, as long as its springs remain inactive, or locked. We see at once that, for any one span whose damping constant under any loading is p, the amount of impact is directly proportional to its loaded frequency, n, and β. But n is a function of the total deflection, as shown in equations (1) and (2), and its value becomes smaller as the deflection increases, that is, with an increase in load. With the same relative amount of hammer blow, β, the impact will become less as the load on the span becomes greater. But $\beta = \frac{D_h}{D}$, so that, under the same condition of loading, the amount of impact varies directly with the amount of hammer blow, as defined by D_h. These two facts must be kept in mind, when comparing various impact tests, and explain the statement, made earlier in this paper, that the mere *ratio* of the measured oscillation to the deflection, or $\frac{h}{D}$, is of but little importance. Probably most, if not all, tests are made with loads much under the capacity of the span, and the impact ratios are high, but we are only interested in knowing the amount of impact when the span is so loaded that the designing or rating stress is approached. Lack of appreciation of this fact has resulted in formulas giving high impact values, and has caused so much confusion that it may be worth while to illustrate the point with a particular example.

Let us take a 100 ft. deck girder designed for a live load of E-70, with a working stress of 18,000 lb., the dead load deflection, d, being 0.216 inch. First assume that an E-40 loading be run over the bridge, the hammer blow of the locomotive being such that the resulting deflection D_h, at 1 r.p.s. is .00297 inch., the static live load deflection D, being 0.554 inch.; then $\beta = \frac{D_h}{D} = .00537$. The loaded frequency n, will be approximately, $\sqrt{\frac{12}{d+D}} = 3.95$. Assume that the damping constant, p, for such a span will be .029. Then the locomotive impact at synchronous speed, 3.95 r.p.s. is, from equation (22), $100 \times \frac{.00537 \times 3.95}{.058} = 36.6$ per cent. If the live load be increased to E-70, D becomes 0.970 inch. With a proportionate increase in hammer blow, β remains the same. The natural frequency, n, under this load, is 3.18, and the impact is $100 \times \frac{.00537 \times 3.18}{.059} = 29.4$ per cent. With a rating stress of 26,000 lb., the load, taking into account the ever-decreasing amount of impact, would be about E-110, which would produce a live load deflection, D, of 1.523 in. The frequency would be 2.62, giving an impact of 24.2 per cent, which is about two-thirds of that under the E-40 loading, with which the span might have been tested.

The different impact percentages, as found above, are all based on one value of β, that is, a fixed intensity of hammer blow, relative to the live load. With a change in this factor, the impact would vary proportionately, so that any comparison between various sets of measured impacts is only misleading, unless there be taken into account not only the relation of the hammer blow to the live load, but also the relation of the load to the capacity of the span. And there is still one other condition to be considered. Even with the same β, and the same load-capacity ratio, larger impacts will be found in deep stiff spans than in shallow spans, as in the former the loaded frequency will be higher than in the latter. The difference is quite large when we compare a 120 ft. deck girder, which may have a loaded frequency of about 2.4, with a 120 ft. through truss, which, with the same intensity of stress, may have a frequency of 4.20. The damping constant, p, of the truss span would be somewhat larger, but even with this correction, the impact in the truss span would be from 30 to 40 per cent greater than that in the deck girder.

Values of the dynamic magnifier for different ratios of the frequency of the disturbing force to the natural frequency of the span, $\frac{N}{n}$, and for various values of Δ, as given by the equation, $k = \frac{1}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(\Delta \, . \, \frac{N}{n}\right)^2}}$, have been plotted in Fig. 8.

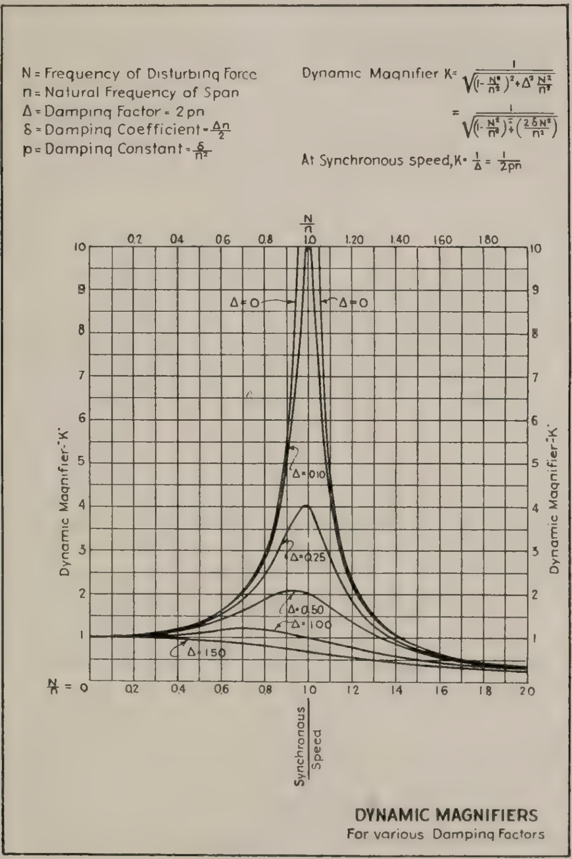


Fig. 8

It should be noted that, when the amount of damping, Δ, is comparatively small, its effect, on the value of k, is small when $\frac{N}{n}$ is less than 0.8 or greater than 1.2. For larger values of Δ, say 0.5 or more, it is effective throughout a much greater range of $\frac{N}{n}$. It should also be noted that with the larger amounts of damping, the dynamic magnifier is a maximum when $\frac{N}{n} < 1$. The product of the hammer blow deflection,

$D_h N^2$, and the dynamic magnifier, k, corresponding to the speed N, is the semi-amplitude of the oscillation, $(h = k\,D_h\,N^2)$ and it is a maximum when $\frac{N}{n} > 1$, especially when Δ is large. That is, we have what may be called a *critical speed,* at which the oscillations may exceed, by a small amount, those at synchronous speed. This will be found in many of the diagrams in Appendix B, being more noticeable in the shorter spans.

The equation for the dynamic magnifier, $k = \dfrac{1}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(\Delta\,.\,\frac{N}{n}\right)^2}}$, is particularly useful in the determination, from a series of tests, of the damping factor, Δ, as the oscillations need not necessarily be recorded at the exact synchronous speed. Whenever the speed is within 10 or 15 per cent of synchronism, quite accurate values of this factor can be obtained as long as the locomotive springs remained locked. Having measured the live load deflection, D, and arrived at the deflection factor, the hammer blow deflection, D_h, and the dead load deflection, d, can be calculated, and the natural frequency, n, determined from whichever one of the formulas, (1), (2) or (3), corresponds to the condition of loading. From the test record, the speed, N, and the height h, of the oscillation are known. By definition, $k = \frac{h}{D_h\,N^2}$, and substituting its real value in the above equation for the dynamic magnifier, the value of Δ can be found. As an example, assume that an oscillation of 0.068 inch. has been obtained in a test when the locomotive was running at a speed of 2.7 r.p.s., on a span whose loaded frequency, n, is 3.0, and that the hammer blow of the locomotive at 1 r.p.s., acting at the center of the span, produces a deflection D_h, of .0031 inch. $D_h\,N^2 = .0226$ inch, and the dynamic magnifier $k = \frac{h}{D_h\,N^2} = \frac{.068}{.0226} = 3.01$, and $\frac{N}{n} = \frac{2.7}{3.0} = 0.90$. 'Substituting these values in the equation, $k = \dfrac{1}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(\Delta\,.\,\frac{N}{n}\right)^2}}$, the damping factor, Δ, corresponding to this particular loading, is found to be 0.303.

From equation (18), $\Delta = 2p\,n = \frac{2\delta}{n}$, we find that, for any condition of loading, the damping constant of the span, $p = \frac{\Delta}{2n} = \frac{.303}{6.0} = .0505$, and the damping coefficient, under the particular load used in the test, is $\delta = p\,n^2 = .4545$. If the damping were due only to elastic friction, the oscillations would die out in the ratio of $e^{-2\pi\,.4545} = .0575$. As previously explained, there are other forms of damping, such as friction in the end bearings, and the value of Δ, obtained in the manner just described, really covers all forms of damping which were present. However, most tests are made with loads considerably below the carrying capacity of the span, and if it be assumed that the amount of damping, obtained experimentally by such a test, will decrease with an increase in load, as would be the case if it were all in the form of elastic damping, we are well on the safe side when estimating the impact for the fully loaded bridge.

In the example just cited, assume that, when the load is increased so that the span will be stressed to 18,000, its frequency is 2.5. Having found the damping constant, p, to be .0505, the new Δ, corresponding to this heavier loading, is $2p\,n = .101 \times 2.5 = .2525$. The dynamic magnifier, k, at synchronous speed, see equation (20), is $\frac{1}{\Delta} = 3.96$, as compared with 3.01 for the lighter test loading.

The method, which has just been illustrated, was used for determining the damping characteristics of all of the spans tested. The value of k was computed from the test data. After k was known, the damping factor, Δ, for that particular load and frequency, and the damping constant, p, for any load or frequency, could be found. Having p, the new Δ, for any loading, such as full capacity loading, could be estimated. On account of the bearing friction, it is quite probable that Δ does not decrease directly with a decrease in the frequency n, in which case the magnifier, k, would remain more nearly constant for any condition of loading. But until we become better informed as to these damping forces, it is safer to assume, as long as we are testing with light loads, that they will be less effective under heavy loads. We need not concern ourselves about the amount of impact in a bridge when the other stresses are small, but when the structure is so heavily loaded that the stress approaches its permissible intensity, we must be sure that the impact allowance, under that condition, is adequate.

Spans of Intermediate Length

CASE II. ON WHICH THE LOCOMOTIVE SPRINGS ARE ACTING

Thus far in the discussion of impact on spans of intermediate length, we have considered only the case in which the springs remain locked. On certain spans in this group, say between 40 and 175 ft. in length, spring action may be induced, and the spring friction and the oscillation of the sprung weight contribute a large amount of additional damping, which reduces the magnitude of the oscillations at the higher speeds. But when the sprung weight is oscillating, the bridge is relieved of a portion of the load, a second and higher synchronous speed occurs, and the oscillations at this speed may exceed those which would have been found had the springs remained locked.

Spring action may take place when the forced vibrations in the span become either so great or so rapid that the acceleration of the sprung mass of the locomotive produces a force greater than the friction in its springs. The same is undoubtedly true as to the cars and tender, but inasmuch as the spring frequencies of these other units will be quite variable, depending upon the amount of load they carry, and differ not only in period but in phase, from those of the locomotive, their effect will be ignored in the analysis, and only the effect of the locomotive springs will be considered. Any additional damping, contributed by the train or tender, will be just that much on the side of safety.

If h is the semi-amplitude of the oscillation, in inches, measured from the mean deflected position of the span, when the forced vibrations have a frequency of N times per second, the acceleration, a, is:

$$a = \frac{4\pi^2 N^2 h}{12} \qquad (23)$$

If, at the point on the span where the oscillation is measured, we have a locomotive whose equivalent concentrated sprung mass is $\frac{W_s}{32.2}$, the force, G, acting on this mass, due to the acceleration of the vibrating bridge, is $a \cdot \frac{W_s}{32.2}$, or:

$$G = .1022 W_s N^2 h \qquad (24)$$

If the locomotive spring friction F^1, in pounds, is expressed in terms of its sprung weight, i.e., $F^1 = r \cdot W_s$; just as the oscillations become of such magnitude that the force G becomes equal to the friction, $G = F^1 = r \cdot W_s$, and

$$h = \frac{r}{.1022 N^2} \qquad (25)$$

From this equation, we can find the height of the oscillation, in inches, at any frequency N, which will just overcome the spring friction F^1, when F^1 is expressed as a proportion, r, of the sprung weight of the locomotive. Not a great deal is known as to the actual amount, in pounds, of this friction force. In the tests there was little if any evidence that spring action occurred when r was less than 0.10, and when spring action did take place, r was seldom found to be greater than 0.15.

In estimating the magnitude of the oscillations which may be expected when the bridge is subjected to the additional damping force introduced by spring action, it is necessary to take into account the amount of friction, the spring frequency, the spring damping, the mass of the sprung weight, the span frequencies and span damping. In the Report of the Bridge Stress Committee,[4] this problem is dealt with by the use of vectors, but Professor Inglis[9] later developed an analytical method, and has since[10] further simplified his original solution. While its application is still somewhat laborious, it does provide a means of attacking this special problem, and seems to give values which are safe at least. It is suggested that the reader consult both of these papers by Professor Inglis, in order to fully understand the solution, as only the equations necessary for our purpose will be given here, and they have been changed somewhat as to form.

His general equation (equation 16, page 32) has been given in terms of the dynamic magnifier, k, but as an expression of the height of the oscillation, h, at the center of the span, it may be written:

$$h = D_h N^2 \sqrt{\frac{(N^2 - n_s^2)^2 + (2N\Theta)^2}{\phi^2 + \psi^2}} \quad \text{.......} \quad (26)$$

In which, after substituting p, for $\frac{\delta_o}{n_0^2}$, in equations (16a) and (16b),

$$\phi = \frac{N^4}{n_1^2} - N^2 \left[1 + 4p\Theta + \frac{n_s^2}{n^2} \right] + n_s^2 \quad \text{.......} \quad (26a)$$

$$\psi = 2N \left[\Theta \frac{n^2 - N^2}{n^2} + p(n_s^2 - N^2) \right] \quad \text{.......} \quad (26b)$$

Repeating for convenience, that:

N = the frequency of the hammer blow, in r.p.s.
n_s = the natural frequency of the locomotive springs.
n_1 = the natural frequency of the span, when loaded with the train, tender and unsprung weight of the locomotive.
n = the natural frequency of the span, when loaded with the train, tender and entire locomotive.
n_o = the natural frequency of the unloaded span.
Θ = the damping coefficient of the locomotive springs.
δ_o = the damping coefficient of the unloaded bridge.
p = the damping constant of the span.
d = the central deflection of the span due to its own weight.
D = the central deflection due to the total live load.
$D_h N^2$ = the central deflection caused by the hammer blow of the locomotive acting statically at the center, when running at N r.p.s.
Q = the equivalent concentrated force, which, when placed at the center of the span, will produce the same deflection, D_h, as the distributed hammer blows when operating at 1 r.p.s. At N r.p.s., this force becomes $Q N^2$.
W_s = the equivalent concentrated load which produces the same deflection as the distributed sprung weight of the locomotive.
f = the second and higher critical frequency, at which the maximum oscillation may occur.
g = 32.2.
F^1 = the equivalent concentrated friction of the locomotive springs, in lb.
$F^1 = r \cdot W_s$ when expressed as a proportion r, of the sprung weight.
h = the semi-amplitude of the oscillation at the center of the span.

The spring friction may be independent of velocity but, for convenience, Professor Inglis, in his analysis, substitutes a force varying harmonically with time, the crest value of F^1, being equal to $\frac{4F}{\pi}$, consequently $F = \frac{\pi . r . W_s}{4}$; $\frac{W_s}{F} = \frac{4}{\pi r} = \frac{1.273}{r}$, and $\frac{W_s}{F g} = \frac{.0395}{r}$.

A close approximation of the second higher synchronous speed, f, can be obtained from the following quadratic equation; using the larger root:

$$f^4 - f^2 n_1^2 \left(1 + \frac{n_s^2}{n^2} \right) + n_1^2 n_s^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (27)$$

This is equation (26a), after substituting f for N, and omitting the term $4p\,\Theta$, which is usually small, and Θ is unknown until f is known.

The value of the spring damping coefficient, Θ, for any value of N, can be found by using the positive root, obtained by solving the quadratic equation:

$$\left[\frac{2\pi^3 D_h N^5 W_s}{F g} \right]^2 \Theta^2 = \left[\frac{N^4}{n_1^2} - N^3 \left(1 + 4p\,\Theta + \frac{n_s^2}{n^2} \right) + n_s^2 \right]^2 +$$

$$4N^2 \left[\Theta \frac{N^2 - n^2}{n^2} + p(N^2 - n_s) \right]^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (28)$$

After the values of Θ, for the various values of N, have been determined, the height of the oscillation, h, in feet, for the corresponding values of N, can be found from the equation:

$$h = \frac{F g \sqrt{(N^2 - n_s^2)^2 + (2N\,\Theta)^2}}{W_s \, 2\pi^3 N^3 \Theta} = \frac{r . \sqrt{(N^2 - n_s^2)^2 + (2N\,\Theta)^2}}{2.454 \, N^3 \Theta} \quad \ldots\ldots\ldots \quad (29)$$

When the second synchronous speed, f, is within the range of possible speeds, that is about 7 r.p.s., the oscillations, at or near that speed, may be greater than those which would have occurred, had the springs remained locked. The magnitude of the oscillation at this second and higher speed, or when $N = f$, can be found from equation (28), omitting the first term on the right hand side since, under this condition, its value is zero, and:

$$\Theta = \frac{p(f^2 - n_s^2)}{\frac{1.227 \, D_h f^4}{r} - \frac{f^2 - n^2}{n^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

Having found the value of Θ, when $N = f$, the oscillation, h, in feet, at that speed, is:

$$h = \frac{r \sqrt{(f^2 - n_s^2)^2 + (2f\,\Theta)^2}}{2.454 \, f^3 \Theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (31)$$

Fig. 9 shows the theoretical value of the oscillations, at various speeds and for two amounts of spring friction, as found from equations (27), (28) and (29), for Case II, that is with the locomotive springs working. This diagram also shows the computed oscillations, assuming that the springs remain inactive or locked, Case I.

The effect of spring damping is apparent. Assuming 10 per cent spring friction, the oscillations become equal to $\frac{.10}{.1022 N^2}$, at about 2.75 r.p.s. Due to the large amount of damping contributed by spring friction, the oscillations at first decrease, reaching a minimum value at 3.75 r.p.s., after which they increase rapidly and become a maximum at

5.75 r.p.s. At this second and higher synchronous speed, their magnitude exceeds that which would have been attained had the springs remained locked, so that with this low value of spring friction Case II would give the greater amount of impact.

When the spring friction is 15 per cent, the same action takes place, but due to the larger amount of damping, the oscillations are considerably lower at the higher speed and for this particular span Case I would govern in fixing the amount of impact, if the spring friction were as high as .15 of the sprung weight.

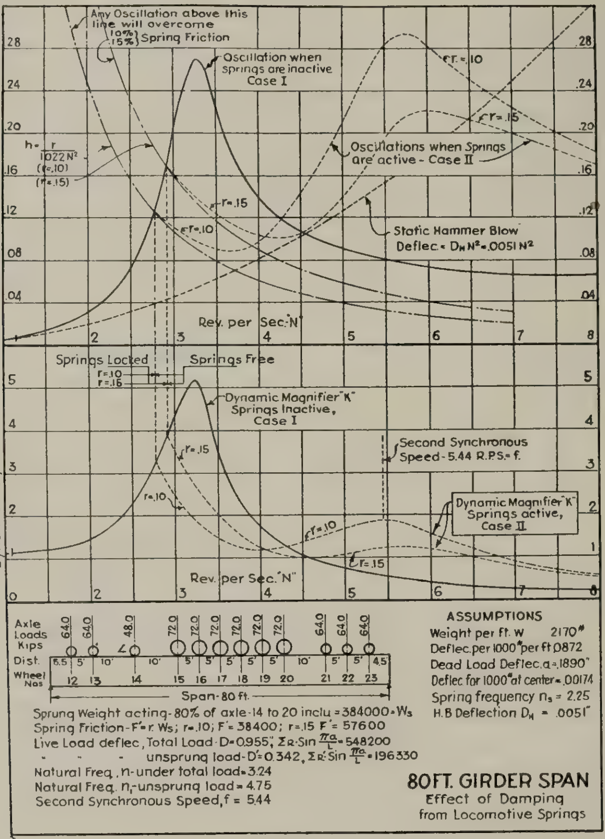


Fig. 9

When considering spans of intermediate length, that is, say from 40 to about 175 ft. in length, the maximum oscillation should be calculated for both conditions; Case I, assuming that, due to some unsuspected condition of the locomotive, its springs may remain locked, and Case II, that they may be free, and the larger used for determining the resulting amount of impact. When *f*, the second synchronous speed, is found to be within 20 to 25 per cent, either way, of the maximum attainable engine speed, the oscillations at this second speed are likely to be the larger, and Case II will govern.

The maximum oscillation at synchronous speed for Case I can be obtained from equation (21), $h = \frac{D_h \, n}{2p}$, and for Case II, from equations (27), (30) and (31).

(3) The Impact from the Locomotive on Long Spans

For the purpose of this study, long span bridges will be considered as those whose length is greater than about 175 ft. On such spans, the forced vibrations may be of considerable magnitude, but they are so slow that spring friction is not overcome, and the entire engine acts as a unit, there being no spring damping. On the longer spans in this group, as shown in Fig. 5, the disturbing force, or hammer blow, may be nearly in tune with the natural frequency of the span, for the greater portion of the time required to cross the bridge, and its effect is greatly magnified. But the force $Q\,N^2$, producing the vibration, is small because N is small, and $D_h\,N^2$, the static hammer deflection is small, so that, even if the dynamic magnifier, k, is large, the oscillations, $h = k\,D_h\,N^2$ at synchronous speed, are not excessive.

The assumption, that the locomotive is stationary and slipping its drivers, as used in the analysis of spans of intermediate length, may not be theoretically applicable to the study of long spans. In the latter the amount of damping is small, and it is conceivable that the oscillations, caused by the stationary driver rotating at the center, might not reach their maximum, either as to magnitude or in the same time, as would have been the case had they been caused by the locomotive moving across the span.

Professor Inglis[9] has derived an equation, based on a moving alternating force, which is the actual condition existing on all bridges, and has assumed, for the sake of simplicity, a constant frequency of the loaded span. The equation will not be given here, but it defines the oscillation for any position of the load, and at any speed. For predicting the maximum oscillations which will occur at synchronous speeds, he has suggested the following equations, which have been altered to conform with the nomenclature used heretofore.

When the alternating force, or hammer-blow, has reached the center of the span, the dynamic magnifier is:

$$k = \frac{1}{2} \cdot \frac{N\,\delta}{Z^2 + \delta^2} \quad \text{(32)}$$

in which $Z = \dfrac{V}{2L} = \dfrac{\textit{Velocity of the train in f.p.s.}}{\textit{Twice the Length of the Span.}}$

If c = the circumference of the drivers, in feet, $Z = \dfrac{N\,c}{2L}$.

The maximum oscillation occurs when the alternating force has passed a short distance beyond the center, at which time:

$$k = \frac{1}{2} \cdot \frac{N}{\sqrt{Z^2 + \delta^2}} \quad \text{(33)}$$

Letting $N = n$, $Z = \dfrac{N\,c}{2L}$, and $\delta = p\,n^2$, this equation may be written:

$$k = \frac{1}{2p\,n} \cdot \frac{L}{\sqrt{\dfrac{c^2}{4p^2\,n^2} + L^2}} \quad \text{(33a)}$$

When the stationary revolving driving wheel was used as the basis for the study of intermediate spans, the maximum dynamic magnifier, at synchronous speed, was found to be, $k = \dfrac{1}{2p\,n}$ (equation (20)). Then the term $\dfrac{L}{\sqrt{\dfrac{c^2}{4p^2\,n^2} + L^2}}$, represents the difference in the value of the dynamic magnifier, at synchronous speed, as found by these two methods. Assuming that c, the driver circumference, = 0, the term becomes equal to unity, and the two equations are identical; i.e., the driver is rotating, but has no forward motion. Assume a span 200 ft. long, whose damping constant is .025, and whose loaded frequency is 3.5. For drivers of 16 ft. circumference, the value of this term is about 0.91, and for a 20 ft. circumference, it is about 0.87. It would seem then that with a known value for the damping constant p, the estimated dynamic magnifier, as determined by equation (33a), would be from 10 to 15 per cent lower, than if the formula, $k=\frac{1}{2pn}$, based on the stationary oscillation method, had been used. But if k had been found experimentally, and we wished to determine the damping constant p, smaller values of the constant would be obtained by using equation (33a).

Except for certain locomotive factors, such as the friction, damping and frequency of its springs, the only lack of information which seems to stand in the way of arriving at a pretty definite conclusion as to the amount of impact in a bridge, is the bridge damping, and the determination of this factor was the principal purpose of the tests. As the exact natural frequency of the span was not known when the field records were being taken, it was only by chance, if a test were obtained at synchronous speed, so that the simple equation (33a) could not be used to determine the value of p, because the value of k, at synchronous speed, was not known. For the non-synchronous case, the corresponding general formula was tried, but it did not fit the actual tests through a range of speeds, and it was finally discarded in favor of the same method which was used on spans of intermediate length, Case I, for which the dynamic magnifier is: $k=\frac{1}{\sqrt{\left(1-\frac{N^2}{n^2}\right)^2+\left(\Delta\frac{N}{n}\right)^2}}$. This equation is easily applied, and provides a satisfactory method of arriving at the value of Δ, from which p can be found, providing the speed of the locomotive is within 10 or 15 per cent of the synchronous speed. It is admitted that the damping factors as obtained by this method may be 10 or 15 per cent higher than those given by the formula based on the moving pulsating force, but if the damping constants, as derived by the application of this formula to a series of tests are used in the same equation for estimating the dynamic magnification in similar spans, the error, if any exists, will be small and on the safe side. When we are able to determine the separate effect of each of the several damping forces, a greater refinement may be justified. The theoretical oscillations and dynamic magnifiers, as computed by the method which was finally chosen, agree very well, through a wide range of speed, with the measured values, as will be found in Appendix B.

(f) Impact Caused by Irregularities in the Track or Wheels

A low, open, or battered joint, or badly burned spots on the rail, may have a noticeable dynamic effect on the bridge, especially on short spans. The same may be said of wheels which are rough, out of round, or eccentrically mounted.

The exact effect of these inequalities depends upon the velocity of the train, the relative amount of sprung and dead weight of the equipment, the deflection and frequency of the springs, track, and bridge, and the particular form or outline of the track or wheel irregularity. There are so many variables entering into the problem, that about all that can be done at this time is to make an approximation.

The condition most to be feared, is that a driver, when running at or near synchronous speed, should strike a low spot near the center of the span, just at the instant when its counterweight is in the angular position to produce the maximum downward oscillation. It is only by chance that this condition obtains during a test. On several short spans which were tested, a rail joint was at or near the center, but only in a very few instances could its effect be recognized with any certainty.

The Bridge Stress Committee[4] seems to have encountered a like difficulty in determining this effect experimentally, even though on one or more bridges tests were made with both continuous and jointed rails. It finally suggested, for purposes of design, that an allowance for this form of impact be provided, by assuming a central concentrated load per track, of $375N^2$ pounds. Considering the heavier power in use in this country, a concentrated load of $500N^2$ pounds per track, in which N is the synchronous speed in r.p.s., should be ample. For an E-80 loading, this gives a maximum impact allowance of about 35 per cent which occurs on an 8 ft. span, decreasing to about 1 per cent on a 100 ft. span. In terms of span length, this impact, in percentage of the live load, is very nearly:

$$\text{Low Joint Impact} = \frac{325}{L} \quad \text{(34)}$$

The effect of wheel irregularities is noticeable to some extent, particularly with passenger cars running at high speeds. The vibrations, which are set up seem to have a frequency corresponding to the r.p.s. of the wheels. This fact would seem to indicate that the effect is not due to flat spots which, if they existed at all, would be quite numerous, but rather to some other form of irregularity which occurs only once in the circumference. This points to eccentricity either in the wheel contour or mounting. These oscillations are quite rapid, having a frequency of about 9, when the cars with wheels of 33-inch diameter are traveling at 60 m.p.h. In some instances they amount to 10 or 15 per cent of the static deflection caused by the train, but the weight of such equipment is so much less than the locomotive or heavy freight cars, that it is never the governing impact condition and can be neglected.

Generally speaking, we should expect to find the wheels of freight cars in a worse condition as to wheel treads or eccentric mounting, and causing greater oscillations. They are seldom apparent, however, perhaps on account of slower speed, but such equipment, due to other causes, does produce quite violent vibrations. These will be discussed under the Subject of Car Impact.

(g) Impact from Smoothly Rolling Loads

A group of wheels rolling smoothly across a beam may induce vibrations but, even under the worst condition, the increase over the static deflection is so small that as a force producing impact, it can usually be neglected. For this reason only a small allowance need be provided for the dynamic effect of electric or motor-driven locomotives, which have no unbalanced revolving weights. With the use of such equipment however, an allowance must be made for the effect of track or wheel irregularities, just as for steam locomotives, and for the effects of the cars which they may be hauling.

(h) Impact from Freight Cars

Inasmuch as the deflectometer records were taken during the movement of the entire train, a good deal of information was gathered as to effect of practically all types of cars, under many conditions of loading. There is no doubt but that some freight cars may cause oscillations of such magnitude that they cannot be ignored in fixing the impact allowance on the longer spans at least.

The car springs have a certain period of vibration which depends upon the spring constant and their deflection, or the load which they support. It is probable that the principal cause of spring vibration is the periodic blow from the rail joints, and if the speed of the car were such that the frequency of the application of these impulses synchronized with the spring frequency, the oscillations would become cumulative. Since the spring frequency depends largely upon its deflection, that is upon the load which it supports, it is clear that with a fixed spacing of rail joints the critical speed for cars of one type and design depends upon the extent to which the cars are loaded. This accounts for the condition which is frequently observed, that is, the bouncing of a few cars in the train while the others are comparatively quiet.

The rail joints on a bridge usually have a more rigid support than those in the ballasted track, and the cause of spring vibration is a little more speculative, but its effect is plainly revealed. The oscillation of the sprung weight of the car sets the span in motion, and its oscillations build up rapidly and become of considerable magnitude. These bridge oscillations may last but a very short time, or during the passage of but one or two cars, after which they may subside and the crawl deflection line remain perfectly smooth until some other car or cars in the train produces a similar effect. Cars of a certain type and design when similarly loaded, may cause large vibrations, while others do not.

There is some reason to believe that with trains made up of cars of the same class, similarly loaded, and whose spring frequencies coincided both as to time and phase, the forced vibrations might become quite large. In meat, oil, and coal trains, this very condition, as to similarity in type of equipment and loading obtains, and on long spans, heavy cars produce a static stress which is quite as large as that caused by the locomotive. On such bridges the locomotive impact is small, and may be less than the impact caused by the train.

The friction in the car springs should have a tendency to damp out the bridge vibrations, and the friction should be greater in the heavily loaded cars. No definite information as to the effect of this damping force on bridge oscillation is available, but the use of car spring snubbers is now being investigated, and if such a device were generally adopted it should reduce the amount of car impact in bridges as well as damage to the car contents.

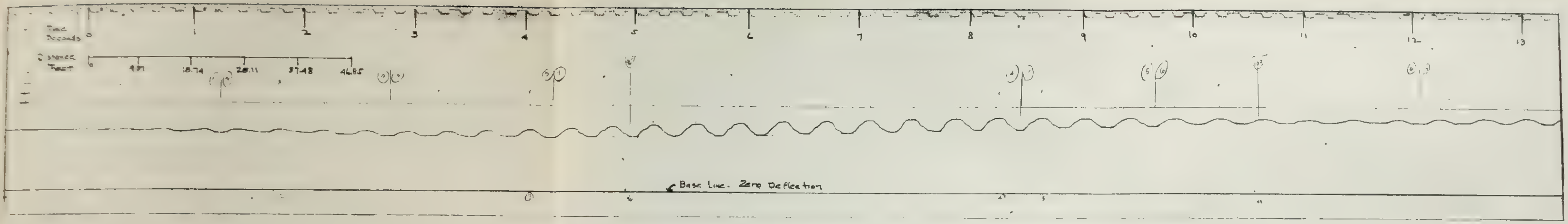
In Fig. 10, some original records showing the vibrations caused by freight cars are reproduced.

(i) Rolling or Swaying of Locomotives and Cars

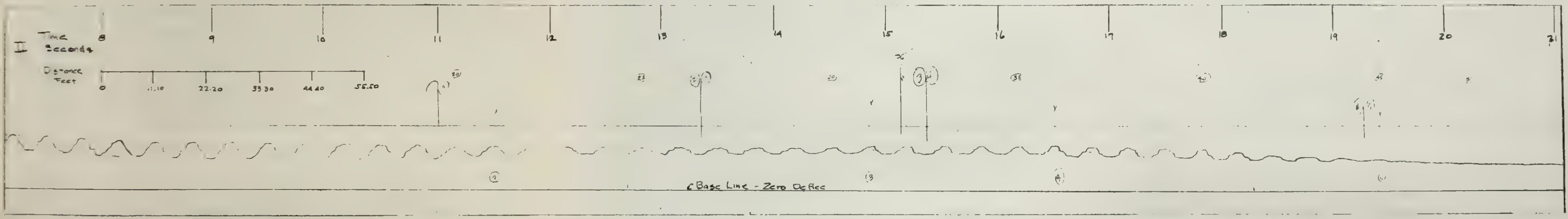
That portion of the cars and locomotives which is spring borne may rotate about a longitudinal axis with a periodic motion, as well as oscillate in a vertical direction. The sprung weight has the motion of an inverted pendulum and is subjected to a disturbing force, transmitted through the springs, which usually originates in certain track irregularities. Where track inequalities, such as rail joints, occur at regular intervals, and the speed of the train is such that the spring and pendulum frequencies and the disturbing force become synchronized, the rolling is harmonic in character and may become excessive in amount. This is particularly true of freight cars but, fortunately, they seem to lose most of this motion just as soon as they enter the bridge.

The locomotives give very little trouble in this respect, especially those of modern design. With the introduction of the trailing wheels the points of support in the rear were placed farther apart and lower, and a ride in the cab of such an engine is quite different from what it was in one of an earlier type.

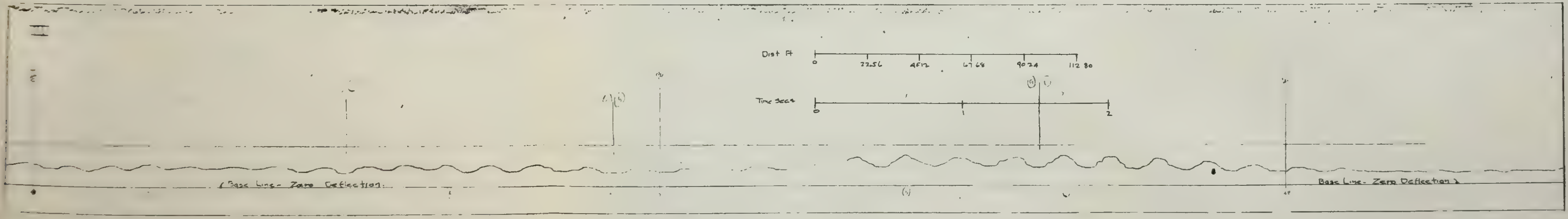
Regardless of the amount of roll of either the locomotive or cars on track, it is difficult to conceive how this action can be dynamic, in its effect on a bridge, to any serious extent. On short spans, there could be but one application of the force caused



I—Oscillations in 224 ft. Through Truss; Span No. 4; Record B-419; Speed 13 M.P.H.



II—Oscillations in 184 ft. Through Truss; Span No. 6; Record A-542; Speed 17.4 M.P.H.



III—Oscillations in 138 ft. Through Truss; Span No. 9; Record **B**-577; Speed 43.5 M.P.H.

FIG. 10—Vibrations Caused by Freight Cars.

by rolling, and when the span is long enough to include the tender and cars, the effect of the rolling of these other units tends to offset that of the locomotive. The adjacent cars in the train are usually found swaying in opposite directions and due to the difference in their spring design and loading, their period of roll is likely to be quite different.

The deflectometer records offered a means of estimating the effect of rolling or swaying on bridges, and this was found to be small. There was no indication of a dynamic action, the deflections simply registering an increase of load on one rail, while the other was relieved of a like amount. This being true, the effect of engine or car roll can best be provided for, by an increase in the static live load.

(j) Impact in Shear Members

The present impact formula of the A.R.E.A. specifies that in computing the impact in the various members of a span, the loaded length be used for the term *L*. This provides a greater allowance for impact in shear members, especially those near the center than it does for bending, as in the latter case the span is loaded throughout its length. As has been stated, no stress measurements were taken during the tests, but in the Report of the Bridge Stress Committee,[4] the results of such tests on several spans are given, and it was found that the dynamic effect of shear was no greater than that due to bending, and also that this effect was greater at the quarter points than at the center or ends of the span.

Assuming first a beam of length *L*, carrying a load of *w*, pounds per foot, and vibrating *N* times per second in a vertical plane, as shown in Fig. 11.

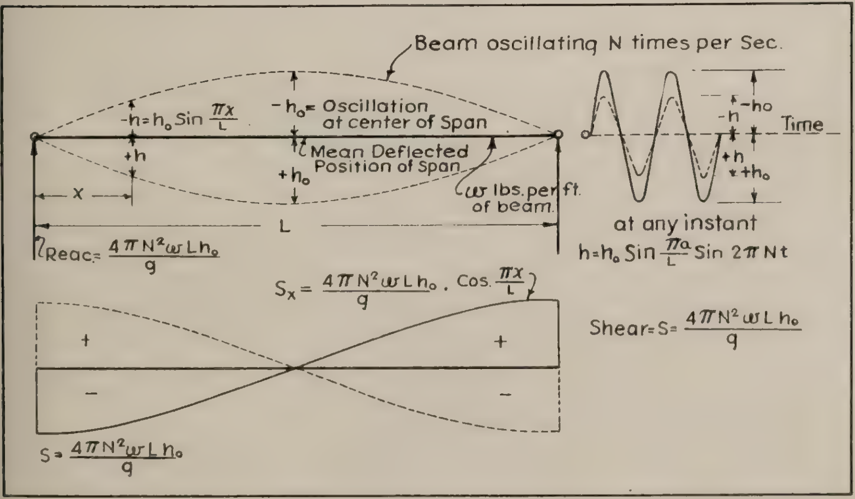

Beam oscillating N times per Sec.
$-h = h_o \sin \frac{\pi x}{L}$
$-h_o$ = Oscillation at center of Span
+h
Mean Deflected Position of Span
$+h_o$
x
ϖ lbs. per ft. of beam.
L
Reac.= $\frac{4\pi N^2 \varpi L h_o}{g}$
$S_x = \frac{4\pi N^2 \varpi L h_o}{g} \cdot \cos \frac{\pi x}{L}$
+
+
–
–
$S = \frac{4\pi N^2 \varpi L h_o}{g}$
$-h_o$
$-h$
Time
+h
$+h_o$
at any instant
$h = h_o \sin \frac{\pi a}{L} \sin 2\pi N t$
Shear = S = $\frac{4\pi N^2 \varpi L h_o}{g}$

Fig. 11. Dynamic Shear in Oscillating Beam Uniformly Loaded

We may say, without great error, that during vibration the beam takes the form of a sine curve, so that if the maximum height of the oscillation at the center, when measured from its main deflected position, is h_o, the oscillation h, at any other point distant

x from one end, is $h_o \, Sin \frac{\pi x}{L}$. The acceleration at this point is $4\pi^2 N^3 h$, or $4\pi^2 N^2 h_o \times Sin \frac{\pi x}{L}$, and for any element dx, the force is $\frac{w}{g} . dx . 4\pi^2 N^2 h_o \, Sin \frac{\pi x}{L}$. The total force exerted by the vibrating beam is:

$$\frac{4\pi^2 N^2 h_o w}{g} \int_o^L Sin \frac{\pi x}{L} . dx = \frac{8\pi N^2 h_o w L}{g},$$

and the end reaction is $\frac{4\pi N^2 h_o w L}{g}$, h_o being expressed in feet.

The shearing force at any section x, is:

$$S_x = \frac{4\pi N^2 h_o w L}{g} - \frac{4\pi^2 N^2 h_o w}{g} \int_o^x Sin \frac{\pi x}{L} . dx = \frac{4\pi N^2 h_o w L}{g} . Cos \frac{\pi x}{L}.$$

It will be seen from this expression, that the dynamic shear at the center is always zero, and that with a constant value of h_o and w, it is a maximum at the ends. It is also true that for any one point on a given span, the shear is proportional to the product of w and h_o.

In a bridge, w, which includes the equivalent distributed weight of the live load, and the central oscillation, h_o, are constantly changing, as the load moves over the span, both usually reaching a maximum value, assuming a speed near synchronism, when the leading wheel of the locomotive is near the three-quarter point. This means that the dynamic shear at any point, x, becomes a maximum when the load is in that position. Inasmuch as this is the position of the live load which produces the maximum static shear in the web members at or near the quarter point, we may expect to find the greatest shear impact in that portion of the span. For a shear member at or near the end of the bridge, the maximum static shear occurs when the bridge is almost fully loaded, but under this condition both w and h_o have become smaller, so that the dynamic shear is less. This is verified by the British tests to which reference has been made.

On the longer spans the live load can be reduced to an equivalent uniform load and added to the dead weight of the span, for the value of w. On short spans, where there are several concentrated loads, spaced relatively far apart, the shearing force due to the concentrations should be considered separately and added to that due to the dead load of the span itself. The case covering concentrated loads is shown in Fig. 12.

With several concentrations the loading will be symmetrical enough in most cases to assume, without great error, that the beam during vibration takes the form of a sine curve. Then the oscillation, h, under the load, R, distant, a, from one end, is $h_0 \, Sin \frac{\pi a}{L}$, and the force, due to the oscillating load R, is $\frac{R . 4\pi^2 N^2 h_o}{g} . Sin \frac{\pi a}{L}$. The dynamic reactions, due to this single load, are, $\frac{L-a}{L} \cdot \frac{R . 4\pi^2 N^2 h_o}{g} . Sin \frac{\pi a}{L}$, and $\frac{a}{L} \cdot \frac{R . 4\pi^2 N^2 h_o}{g} . Sin \frac{\pi a}{L}$. The shearing force, at any section, is determined as for static loads, using the force due to R, that is, $\frac{R . 4\pi^2 N^2 h_o}{g} . Sin \frac{\pi a}{L}$, instead of the load R. For several loads R_1, R_2, R_3, etc., distant a_1, a_2, a_3, the shearing forces, due to each, are combined.

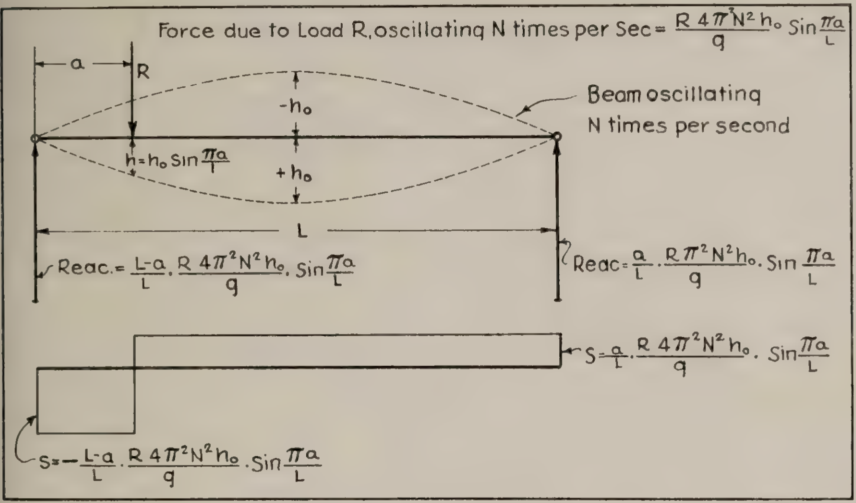

Force due to Load R, oscillating N times per Sec = $\frac{R\,4\pi^2 N^2 h_o}{g}$ Sin $\frac{\pi a}{L}$
a
R
$-h_o$
Beam oscillating
N times per second
$h = h_o \sin\frac{\pi a}{L}$
$+h_o$
L
Reac. = $\frac{L-a}{L} \cdot \frac{R\,4\pi^2 N^2 h_o}{g} \cdot \sin\frac{\pi a}{L}$
Reac = $\frac{a}{L} \cdot \frac{R\,\pi^2 N^2 h_o}{g} \cdot \sin\frac{\pi a}{L}$
$S = \frac{a}{L} \cdot \frac{R\,4\pi^2 N^2 h_o}{g} \cdot \sin\frac{\pi a}{L}$
$S = -\frac{L-a}{L} \cdot \frac{R\,4\pi^2 N^2 h_o}{g} \cdot \sin\frac{\pi a}{L}$

Fig. 12. Dynamic Shear in Oscillating Beam with Concentrated Loads

The dynamic shears have been investigated for two spans which were tested, and the results are given below.

Span No. 6, a six-panel through truss 184 ft. long, and Test B-401 recording the passage of a J1-E locomotive and train, running at 2.95 r.p.s., the calculated loaded frequency under this run being 2.90. The outline of the truss, the loading and several diagrams are given in Fig. 13.

The weight of this span was 2875 lb. per ft., and the dead load deflection, as determined from tests, was 0.5049 inch, giving a deflection of 0.1756 inch per 1000 lb. per ft. The central crawl deflection was scaled from the record, and it will be seen that it reached a maximum when the pilot wheel was about 10 ft. beyond panel point L_4. From the deflections the equivalent uniformly distributed live loads have been computed, and these added to the dead load of 2875 lb., give the total weight per ft. *w*, for various positions of the load, and it reaches its maximum, of course, at the same time that the deflection is a maximum. As a matter of interest, the calculated natural frequency for various positions of the load is shown. This is not to be confused with the period of vibration, as it represents only the frequency of the natural vibrations, while the forced vibrations, with which we are concerned, have the same frequency *N*, as the disturbing force, or in this case, the hammer blow.

In the lower diagram are given the scaled heights h_o, in feet, of the oscillation at the center of the bridge. It will be noticed that in this run they reached their maximum height just before the leading wheel reached panel point L_4, and by the time wheel No. 1 had reached the end of the span, L_6, their magnitude was only about 75 per cent of the maximum. The dynamic shear at any point on the bridge, being proportional to the product of *w* and h_o, will be a maximum, when $w \times h_o$ is a maximum, and this will occur when the first wheel is at or near L_4.

In Table II will be found the value of the dynamic shear at points L_4, L_5, L_6, as calculated from the formula, $\frac{4\pi N^2 w L h_o}{g} . Cos \frac{\pi x}{L}$, for various positions of the load from L_1 to $L_6 + 30.67$ ft. At L_3 it is zero. There is also shown the calculated live-load

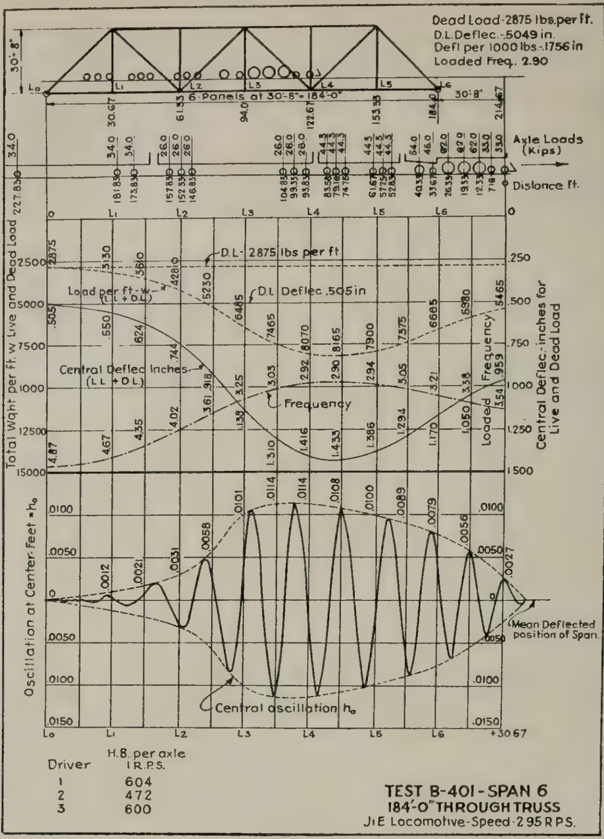


Fig. 13

First Wheel of Locomotive at Panel Point	TABLE II TEST B-401 SPAN 6-184 FT. THROUGH TRUSS IMPACT DUE TO SHEAR																	
	PANEL 3-4						PANEL 4-5						PANEL 5-6					
	Static Shear = S	Dynamic Shear = S_D	Total $S+S_D$	$I=\frac{S_D}{S}$	H Blow Static Shear = S_H	Magnification $q=\frac{S_D}{S_H}$	Static Shear = S	Dynamic Shear = S_D	Total $S+S_D$	$I=\frac{S_D}{S}$	H Blow Static Shear = S_H	Magnification $q=\frac{S_D}{S_H}$	Static Shear = S	Dynamic Shear = S_D	Total $S+S_D$	$I=\frac{S_D}{S}$	H. Blow Static Shear = S_H	Magnification $q=\frac{S_D}{S_H}$
L1		1170			870	1.34		2035			870	2.34		2345			870	2.69
+5.33		2475			2120	1.17		4290			2120	2.02		4950			2120	2.34
L2	70800	4140	74940	5.9	3310	1.25	70800	7160	77960	10.2	3310	2.16	70800	8280	79080	11.7	3310	2.50
+15.33	119800	9470	129270	7.9	4550	2.08	119800	15420	135220	14.1	4550	3.38	119800	18940	138740	15.8	4550	4.16
L3	168800	20445	189245	12.1	5740	3.56	168800	35450	204250	21.0	5740	6.17	168800	40890	209690	24.2	5740	7.12
+15.33	193400	26565	219965	13.7	6920	3.84	223400	45730	269130	20.5	6980	6.55	223400	53130	276530	23.8	6980	7.61
L4	156600	28740	185340	18.3	7580	3.79	283000	49800	333000	17.6	8180	6.09	283200	57435	330635	20.3	8180	7.02
+15.33	86400	27530	113930	31.9	8020	3.43	309800	47730	357530	15.4	9360	5.10	353400	55055	408455	15.6	9420	5.84
L5	50000	24660	74660	49.3	8940	2.75	269800	42760	312560	15.9	10015	4.27	398400	49320	447720	12.4	10615	4.65
+15.33	24800	20490	45290	82.5	10170	2.01	212200	35530	247500	16.8	10445	3.40	431800	40980	472780	9.5	11845	3.46
L6	8000	16435	24435	205.0	11375	1.45	163000	28500	191500	17.4	11375	2.51	404800	32870	437670	8.2	13050	2.52
+15.33	29000	10360	39360	35.7	12045	.85	158000	17960	175960	11.4	12045	1.49	345000	20720	365720	6.0	13670	1.51
+30.67	26800	4605	33205	16.1	8275	.56	108000	7985	115985	7.4	8275	.96	299200	9210	308410	3.1	9350	.98
Impacts and Dyn Magnifiers from Bending	For Moment with Wheel ① at L3 + 15.33 Oscil-.1372" Deflec-.805" Imp = $\frac{.1372}{.805}$ = 17.1% Stat. H.B. Defl. $D_H N^2$ = .0261" K = $\frac{.1372}{.026}$ = 5.27						For Moment with Wheel ① at L4 + 15.33 Oscil. .1300" Deflec-.928" Imp = $\frac{.1300}{.928}$ = 14.0% $D_H N^2$ = .0261" K = $\frac{.1300}{.026}$ = 5.0						For Moment with Wheel ① at L5 + 15.33 Oscil. = .1071" Deflec. .789" Imp = $\frac{.1071}{.789}$ = 13.6% $D_H N^2$ = .0261" K = $\frac{.1071}{.026}$ = 4.12					
	Maximum for Moment-Is for Wheel ① at L3 + 15.33																	

static shear for each panel, and the shear due to the hammer blow operating at 2.95 r.p.s., considered as acting statically and placed in the position which will produce the maximum shear in the panel under consideration. For the live load we may say that the shear impact is the ratio of the dynamic shear to the static shear, and the degree of magnification of the effect of the hammer blow, which we will call q, is the ratio of the dynamic shear to the shear due to the hammer blow, when considered as acting statically.

In panel $L_3 - L_4$, the maximum static shear occurs when wheel 1 is about midway between L_3 and L_4, and this is the shear for which the member would be designed. For this position of the load, the dynamic shear at L_4, is 26,565, giving an impact of 13.7 per cent, and a magnification, q, of 3.84. The dynamic shear is slightly larger when wheel 1 is at L_4, but as this position of the load would not control the design, it can be neglected. At the bottom of the table, the impact and dynamic magnifier, k, for moment are given, and for this position of the load the moment impact is 17.1 per cent and the dynamic magnifier is 5.27; both values being greater than those for shear.

In panel $L_4 - L_5$, the maximum static shear of 309,800 occurs when wheel 1 is about midway between L_4 and L_5, at which time the dynamic shear is 47,730, giving an impact of 15.4 per cent and a magnification of 5.10. For this particular position of the load the moment impact is 14.0 per cent and the dynamic magnifier is 5.0, both somewhat less than the corresponding shear values, but the shear values are still less than the maximum moment values of 17.1 per cent and 5.27, which occur when wheel 1 is at $L_3 + 15.33$ ft.

In panel $L_5 - L_6$, the maximum static shear of 431,800 occurs when wheel 1 is about midway between L_5 and L_6. At this time the dynamic shear, which had a peak value of 57,435 when wheel 1 was at L_4, has dropped to 40,980, the impact is only 9.5 per cent, and the hammer blow magnification is 3.46. For this position of the load the corresponding values for moment are 13.6 per cent and 4.12.

In this span, as was to be expected, the maximum shear impact occurs in Panel 4-5, and this impact is somewhat less than that due to moment.

The same analysis has been made of Span No. 4, which is an eight-panel truss, 224 ft. long. Test B-429 was used, which recorded the passing of an L2-D locomotive and train, running at 2.52 r.p.s., the natural frequency of the span under this load being 2.51. In Fig. 14 are shown the crawl deflection and central oscillation h_o, as scaled from the record, together with the calculated values of the total weight per foot, w, and the natural frequency. There are also shown in the lower diagram, the calculated dynamic shears at panel points L_5, L_6, L_7 and L_8. In Table III are given the computed values of the shear impact and the hammer blow magnification, for the various panels. Under the position of the load which would govern the design of the web members, we obtain the following values:

Panel	*Impact*	*Magnification*
4–5	10.7%	3.40
5–6	15.0%	5.72
6–7	13.4%	5.51
7–8	5.9%	3.05

The critical condition, as far as moment is concerned, occurs when wheel 1 is midway between panel points, L_5 and L_6, at which time the moment impact is 15.5 per cent and the dynamic magnifier is 6.0. Both of these values are slightly higher than those found for shear in panel 5–6, in which they are a maximum.

In plate girder bridges, the shear at the quarter point is of but little importance, as there is always an excess of section in the web at that place. On short spans, the oscil-

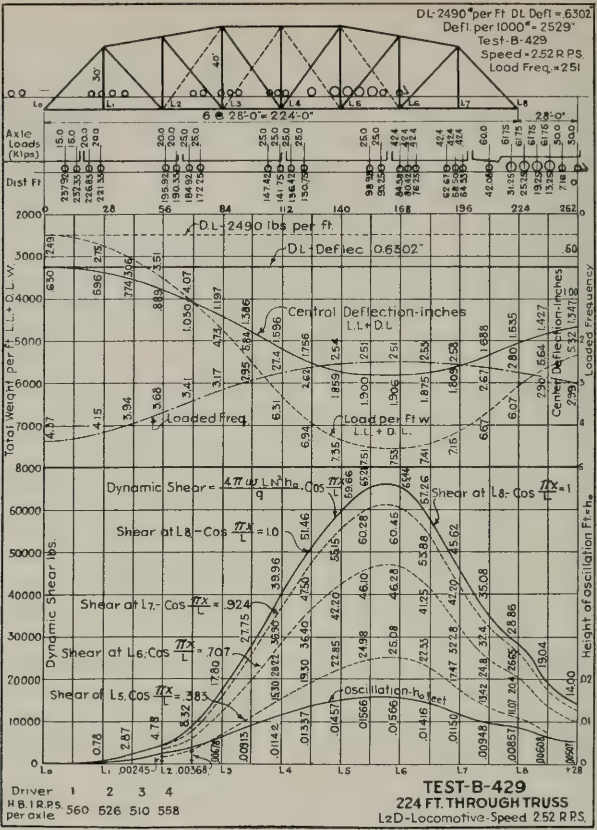


Fig. 14

TABLE III – TEST B-429 – SPAN 4-224 FT. THROUGH TRUSS – IMPACT DUE TO SHEAR

First Wheel of Locomotive at Panel Point	PANEL 4-5						PANEL 5-6						PANEL 6-7						PANEL 7-8					
	Static Shear S	Dynamic Shear S_D	Total Shear $S+S_D$	$I=\frac{S_D}{S}$	H.Blow Static Shear S_H	Magnification $q=\frac{S_D}{S_H}$	Static Shear S	Dynamic Shear S_D	Total Shear $S+S_D$	$I=\frac{S_D}{S}$	H.Blow Static Shear S_H	Magnification $q=\frac{S_D}{S_H}$	Static Shear S_D	Dynamic Shear S_D	Total Shear $S+S_D$	$I=\frac{S_D}{S}$	H Blow Static Shear S_H	Magnification $q=\frac{S_D}{S_H}$	Static Shear S	Dynamic Shear S_D	Total Shear $S+S_D$	$I=\frac{S_D}{S}$	H.Blow Static Shear S_H	Magnification $q=\frac{S_D}{S_H}$
L2	562	183	58.0	3.3	2.07	1.89	56.2	3.38	59.6	6.0	207	1.63	56.2	442	60.6	79	207	2.14	562	478	61.0	8.5	2.07	2.30
+14	85.2	3.19	88.4	3.7	2.95	1.08	85.2	589	91.1	6.9	2.95	2.00	852	7.69	929	9.0	295	260	85.2	8.32	93.5	98	2.95	282
L3	118.4	6.82	125.2	5.8	3.73	1.83	118.4	12.59	131.0	106	3.73	3.37	118.4	16.45	134.9	13.9	3.73	4.40	1184	1780	1362	15.0	3.73	4.77
+14	1776	10.63	188.2	6.0	4.67	2.27	177.6	19.60	197.2	110	467	4.20	177.6	25.64	203.2	144	467	5.50	177.6	2775	205.4	156	4.67	5.92
L4	200.0	15.30	215.3	7.7	5.44	2.82	200.0	28.22	228.2	141	5.44	5.20	200.0	36.90	236.9	18.5	544	6.80	200.0	39.96	240.0	200	5.44	7.34
+14	215.2	19.30	2345	9.0	6.36	3.03	260.2	3640	296.2	14.0	6.37	5.71	260.2	47.50	3077	182	6.37	7.45	260.2	51.46	311.5	19.7	6.37	806
L5	2146	22.86	237.5	10.7	6.69	340	286.6	42 20	328.8	14.7	7.20	5.85	286.6	55.15	341.8	19.2	720	7.66	286.6	59.66	346.3	20.8	720	8.30
+14	95.4	24.98	120.4	26.2	6.53	3.82	308.0	4610	3541	150	8.06	572	332.8	6028	393.1	181	8.07	7.47	332.8	65.21	398.0	196	8.07	8.08
L6	47.8	25.08	728	55.5	6.80	3.69	270 2	46.28	316.3	171	8 38	5.52	380.0	60.45	440.5	15.9	8.89	6.80	380.0	6544	4454	172	8.89	7.36
+14	9.8	22.33	32.1	227.5	763	2.93	196.0	4125	237.2	21.0	8.24	5.00	4034	5388	4573	134	977	551	427.8	5728	485.1	13.4	9.78	5.85
L7	16.8	17.47	34.3	104.0	8.45	2.06	147.4	3228	1797	21.9	8.52	3.79	3684	42.20	410.6	11.4	10.10	417	480.0	4562	525.6	9.5	10.61	4.30
+14	43.4	13.42	56.8	30.9	9.34	1.44	114 8	24 80	139.6	21.6	9.34	2.66	300.0	32.40	332.4	10.8	9.95	3.26	509.2	35.08	544.3	5.9	11.50	3.05
L8	61.0	11.07	72.1	18.2	10.15	109	90.8	20.40	111 2	22.5	10.15	2.01	252 8	26.65	279.5	10.5	10.22	2.60	476.0	28.86	5049	6.1	12.31	2 34
+14	30.6	7.30	37.9	23.8	10.96	.67	63.4	13.46	76.9	21.2	10.96	1.23	221.0	17.59	238.6	7.9	10.96	1.60	408.0	19.04	4270	47	13.10	1.45
+28	.2	5.36	5.6		26.8	.20	34.0	9.90	43.9	29.1	8.73	1.12	1804	12.93	193.3	7.2	8.73	1.48	352.0	14.00	366.0	4.0	10.38	1.84
Impacts and Dyn Magnifiers for Bending	For Bending Wheel ① at L5 Oscil = .1745" Defl. = 1.229" $I=\frac{1745}{1229}=14.2$ Sta. H B Defl. $D_H N^2$ = .0314 $K=\frac{1745}{.0314}=5.65$						For Bending Wheel ① at L5+14 Oscil = .1882" Deflec. = 1.270" $I=\frac{.1882}{1.270}=15.5$ $D_H N^2$ = .0314 $K=\frac{.1882}{.0314}=6.00$						For Bending Wheel ① at L6 +14 Oscil = .1699" Defl = 1.245" $I=\frac{.1699}{1.245}=13.6$ $D_H N^2$ = 0314 $K=\frac{.1699}{.0314}=5.40$						For Bending Wheel ① at L7 + 14 Oscil - .1138 Delf = 1.058" $I=\frac{.1138}{1.058}=10.7$ $D_H N^2$ = .0314 $\frac{.1138}{.0314}=3.62$					

Maximum for Moment is Wheel ① at L5 +14   All Shears are given in kips lation, h_o, may still be quite large, or even of its maximum magnitude, when the first driver reaches the end of the span, and therefore, the end shear impact is about all that need be investigated.

Take for this study a span 20 ft. long, and live load concentrations *R*, consisting of 72,000 lb., on axles, spaced 5 ft. apart, with a hammer blow *Q*, from each wheel at 1 r.p.s., of 525 lb. We will assume two types of girders of this length:

(1) A deep girder, weighing 1290 lb. per ft., which deflects at the rate of .0066 inch per 1000 lb. per ft. The dead load deflection, *d*, is .0085 inch, $wL = 25{,}800$. $\sum R \, Sin \frac{\pi a}{L} = 184{,}250$. $\sum Q \, Sin \frac{\pi a}{L} = 2744$. From which we find that the live load deflection, *D*, is .0974 inch, and $\beta = .0149$. The frequency of this span is so high that synchronism cannot occur, so the dynamic magnifier, $k = 1$. At a speed of 7 r.p.s., the moment impact is $\beta N^2 = 73$ per cent. The central oscillation, $h_0 = D \times .73 = .0711$ inch $= .00593$ ft. Using the equations previously given for the dynamic end shear, for both the uniform load, *w*, of 1290 lb., and concentrated loads *R*, we obtain the following:

Static Shear			*Dynamic Shear*			$Impact = \frac{Total\ Dynamic\ Shear}{L.L.\ Static\ Shear}$
L.L.	*D.L.*	*Total*	*L.L.*	*D.L.*	*Total*	
180,000	12,900	192,900	31,950	2925	34,875	19.4%

(2) A shallow girder weighing 1390 lb. per ft., with the same loading, which deflects at the rate of .0141 inch per 1000 lb. per ft. The dead load deflection is .0196 inch, $wL = 27{,}800$, $D = .2078$ inch, $\beta = .0149$ as before, and the moment Impact $= 73$ per cent, at 7 r.p.s. The central oscillation $h_o = .2078 \times .73 = .15179$ inch $= .01265$ ft., from which we find the following:

Static Shear			*Dynamic Shear*			$Impact = \frac{Total\ Dynamic\ Shear}{L.L.\ Static\ Shear}$
L.L.	*D.L.*	*Total*	*L.L.*	*D.L.*	*Total*	
180,000	13,900	193,900	68,425	6750	75,175	41.7%

It will be noticed that the dynamic effect in shear is much greater in the shallow than in the deep span, due to the greater oscillation h_o, but the impact due to shear is in both cases much less than that due to bending.

The same investigation was made for a 30 ft. span, with the following results:

	Speed N	*Oscill.* h_0 *, ft.*	*Moment Impact*	*End Shear Impact*
Deep	7.0	.00637	49%	20.8%
Shallow	5.75	.01129	42%	25.6%

It would appear that, in simple spans, the allowance made for impact due to moment, is ample to cover the impact in all shear members in the bridge, and is excessive for such members at the center and ends.

(k) SUMMARY

For convenience we may summarize as follows:

For Locomotive Impact:

On short spans, or those under 30 to 40 ft. in length, and in which there is no magnification, the impact in percentage of the live load is:

$$\text{Impact} = 100 \times \frac{D_h N^2}{D} = 100 \times \beta N^2 .$$

On spans of Intermediate Length, say from 30 or 40 ft. to 175 ft. in length:

Case I—The locomotive springs remaining locked. At synchronous speed, expressed in percentage of the live load:

$$\text{Impact} = 100 \times \frac{D_h\, N^2}{D\, 2p\, n} = 100 \times \frac{\beta\, n}{2p} \text{ and at any other speed,}$$

$$\text{Impact} = 100 \times \frac{D_h \cdot N^2}{D\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(2p\, n\,.\, \frac{N}{n}\right)^2}} = 100 \times \frac{\beta\,.\,N^2}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(2p\, n\,.\, \frac{N}{n}\right)^2}}$$

Case II—The locomotive springs working and contributing additional damping at the lower speeds, but with a possible maximum oscillation at a second and higher synchronous speed.

At the second synchronous speed, f, the impact in percentage of live load is:

$$\text{Impact} = 100 \times \frac{r\sqrt{(f^2 - n_s)^2 + (2f\,\Theta)^2}}{D\,.\,2.454\, f^3\,\Theta}$$

$$\text{in which, } \Theta = \frac{p\,(f^2 - n_s^2)}{\frac{1.227\, D_h\, f^4}{r} - \frac{f^2 - n^3}{n^2}},$$

and f is the larger root, obtained from the quadratic equation:

$$f^4 - f^2 n_1^2 \left(1 + \frac{n_s^2}{n^2}\right) + n_1^2 n_s^2$$

The impact so found, assuming that the springs are working, Case II, should be compared with that found by the formula, Impact $= 100 \times \frac{\beta\, n}{2p}$ Case I, and the larger used.

On Long Spans, that is those more than 175 ft. in length, same as Intermediate Spans, Case I, or:

$$\text{At synchronous speed: Impact} = 100 \times \frac{\beta\, n}{2p}$$

$$\text{At any speed } N\text{: Impact} = 100 \times \frac{\beta\, N^2}{\sqrt{\left(1 - \frac{N^2}{n^2}\right)^2 + \left(2p\, n\,.\, \frac{N}{n}\right)^2}}$$

In the above equation, n is the loaded frequency of the span, as obtained by whichever one of the formulas, (1), (2) or (3), fits the condition of loading. For values of the damping constant, p, see Fig. 15.

For track irregularities the impact, in percentage of live load, is:

$$\text{Impact} = \frac{325}{L}$$

For car impact, 15 per cent, when this amount exceeds that from the Locomotive.

For smoothly rolling loads, such as electric locomotives or other equipment having no unbalanced rotating parts. For the low joint and car effect, the impact, in percentage of the live load, is:

$$\text{Impact} = \frac{360}{L} + 12.5$$

The allowances, as given above, will cover the dynamic effect in members, or parts of the span, subject to shearing, as well as bending stresses.

(VI) INFORMATION OBTAINED FROM TESTS

(a) INFORMATION OBTAINED AS TO DEFLECTION FACTORS, DAMPING CONSTANTS AND FREQUENCIES

Before the experimental work had progressed very far, it was realized that the most important information, which could be obtained from the tests, had to do with bridge damping, and the natural frequency of vibration. It was soon found that, if the deflection could be measured or accurately estimated, a close and satisfactory approximation of the frequency could be obtained. This is possible by the use of reliable deflection factors.

From the test values of the dynamic magnifier, *k*, the damping factor, Δ, corresponding to the condition of loading, was found, as illustrated in the example given on page 36. Having Δ, and the frequency, *n*, the damping constant, *p*, for any loading, is $\frac{\Delta}{2n}$. With this information, together with the locomotive characteristics, we should be able to estimate closely the amount of impact to be expected on any simple steel span, except one which is particularly affected by the action of the locomotive springs. In Appendix B will be found one or two diagrams for each test span, showing the comparison, between the actual dynamic magnifiers and oscillations and their theoretical values, based on the damping constants derived from the tests.

For convenience, the deflection factors, deflection constants, and damping constants, are given in Tables IV, V, VI.

The deflection factor, as has been explained, is the ratio of the measured deflection, under some known load, to the theoretical deflection for that load.

For the through trusses, Table IV, the deflection factor was found to vary only from .786 to .840 for the first nine spans. It is higher for spans 10, 11 and 12, but these were old bridges, and the large deflections were due to pin wear and unequal distribution of stress in the pairs of eye-bars. It would seem that, when measured deflections are not available, the actual deflection can be closely estimated by using a deflection factor of .80 for either riveted or pin connected trusses, the theoretical deflection being computed from the gross section and full length of the members.

For deck girder spans with open floor, Table V, the deflection factors are within the range of 1.033 to 1.176, or the equivalent uniform M. of I. was found to be from .850 to .968 of the gross M. of I. at the center. An average value of .90, which was found for most spans, should give, with a very small error, the true deflection, due to bending, in built-up deck girder spans with open floor. When greater accuracy is required, the deflection due to shear should be added. For very deep spans this may amount to 25 per cent of the deflection due to bending.

Deck girder spans with ballasted floor, Table VI. All test spans of this type had concrete decks which had been poured in place. The bond between the slab and the upper flange was sufficient in all cases to develop the longitudinal shear, produced by the test load, and the girder acted as a composite beam. In this table the gross M. of I. at the center is given for the steel section alone, and also for the combined section of steel and concrete. For all spans it was assumed that $\frac{E_s}{E_c} = 8.0$. For the steel section only, the deflection factors varied from about .75 for the long spans to about .60 for the short spans. For the composite section, the corresponding values are 1.10 and 1.25.

No tests were made on spans with decks consisting of timbers or precast concrete slabs laid loosely on the top flanges. It might be expected that such spans would deflect

TABLE IV

TRUSS SPANS - OBSERVED DEFLECTION FACTORS AND DAMPING CONSTANTS

SPAN CHARACTERISTICS							FOR DEAD LOAD ONLY												
Span No.	Type	Span C. to C. of Bearings-'L'	Depth-C. to C. of Chords	$\frac{\text{Span}}{\text{Depth}}$	Wght. per ft. of Span and deck per Trk. = w	Total Weight per track = wL Kips	Unit Stress net Sec bottom chords-'Sd'	Stress per 1000 lbs. per trk. ft. = $\frac{Sd}{.001w}$	Theor.-Deflec. d' (inches)	Observed Deflec. d (inches)	Deflec. Factor = $\frac{d}{d'}$	Deflec. per 1000 lbs. per Trk ft = $\frac{d}{.001w}$	Deflec. per 1000 lbs. at center per track	Deflec per 1000 lbs. Stress = $\frac{d}{.001Sd}$	Natural frequency $n=\sqrt{\frac{12}{d}}$	Observed Damping Constant 'p'	Damping Factor $\Delta=2pn=\frac{2\delta}{n}$	Damping Coefficient $\delta=pn^2$	Dynamic Magnifier at Synchronism $K=\frac{1}{\Delta}=\frac{1}{2pn}=\frac{n}{2\delta}$
1	Riv	547'-4"	90'-0"	6.08	8580	4697.5	11,520	1340	4.518	3.655	.809	.4260	.00150	.3922	1.81	.016	.0579	.052	17.3
2	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
3	"	338'-4"	60'-0"	5.64	5420	1834.6	5900	1090	1.484	1.192	.803	.2199	.00129	.2023	3.17	.021	.1331	.211	7.52
4	Pin Con	224'-0"	40'-0"	5.60	+2300 ○2490	+512.9 ○558.0	+4270 ○4620	1855	+.725 ○.7848	+.5825 ○.6302	.803	.2529	.00248	.1364	+4.54 ○4.36	.0330	+.2996 ○.2878	+.680 ○.627	+3.33 ○3.47
5	Riv.	207'-4"	40'-0"	5.18	4350	902.3	4440	1020	.5955	.4893	.822	.1125	.00109	.1102	4.95	.025	.2475	.613	4.04
6	Pin Con.	184'-0"	30'-8"	6.00	+2685 ○2876	+495.6 ○519.7	+3310 ○3540	1230	+.5601 ○.5996	+.4716 ○.5049	.842	.1756	.00189	.1418	+5.04 ○4.88	.0308	+.3105 ○.3006	+.782 ○.733	+3.22 ○3.33
7	Riv.	150'-0"	32'-0"	4.69	2855	428.8	3580	1250	.3600	.2830	.786	.0992	.00164	.0790	6.51	.0285	.3711	1.207	2.69
8	"	140'-0"	28'-0"	5.00	2920	408.8	3310	1135	.2996	.2517	.840	.0862	.00131	.0760	6.90	.0285	.3933	1.347	2.54
9	"	138'-0"	28'-0"	4.93	2890	398.3	3310	1145	.2995	.2353	.786	.0814	.00123	.0710	7.13	.0300	.4278	1.525	2.34
10	Pin Con.	125'-0"	21'-0"	5.95	1835	229.5	3680	2005	.3620	.3439	.950	.1874	.00352	.0934	5.91	.0376	.4450	1.313	2.25
11	"	122'-3"	27'-3	4.48	1520	186.0	3080	2025	.2558	.2829	1.106	.1861	.00343	.0918	6.51	.0377	.4909	1.598	2.41
12	"	110'-0"	25'-0"	4.40	1680	184.8	2900	1725	.1610	.1455	.904	.0866	.00145	.0500	9.08	.0330	.5993	2.722	1.67

NOTE:-All spans have open type floor. All spans are through trusses except span No. 10 which is a deck truss. All bridges are single track except Span No. 7 which carries two tracks. Spans 1 & 2 are of silicon steel.
For Spans 4 & 6, + refers to tests of Series 1, ○ to Series 2 & 3

TABLE V

DECK GIRDER SPANS WITH OPEN FLOOR - OBSERVED DEFLECTION FACTORS AND DAMPING CONSTANTS.

SPAN CHARACTERISTICS												FOR UNLOADED SPAN - Dead Load Only.																		
								Moment of Inertia						Deflections																
														Bending	Shear															
Span No	Length out to out	Length c to c Bearings L	Depth at center over flange plates	$\frac{\text{Span}}{\text{Depth}}$	Wght per ft, per track, of Span and Deck-'w'	Total wght of Span wL (Kips)	Type of Expansion Bearing	Gross at Center	% of Gross Running full Length	Net at Center	$\frac{\text{Net at Cen.}}{\text{Gross at Cen}}$	Unit Stress calculated from net M of I at Center - S_d	Stress per 1000 lbs per ft of Track = $\frac{S_d}{.001w}$	Calculated from Gross I at Center	% Bending	Calculated Deflection	Total Calculated from Gross I at Center-d'	Observed from Tests d	Deflec Factor = $\frac{d}{d'}$	Deflec per 1000 lbs per ft of Track = $\frac{d}{.001w}$	Deflection per 1000 lb at Center, per track	Deflection per 1000 lbs Stress = $\frac{d}{.001S_d}$	Equivalent Uniform Mom of Inertia = $\frac{\text{Gross at Cen.}}{\text{Deflec Factor}}$	$\frac{\text{Equiv Uniform M of I}}{\text{Gross M of I}}$	Calculated Natural Frequency 'n'	Assummed Natural Frequency	Observed Damping Constant 'p'	Damping Factor $\Delta=2pn=\frac{2\delta}{n}$	Damping Coeffic. $\delta=pn^2$	Dynamic Magnifier $K=\frac{1}{\Delta}=\frac{1}{2pn}=\frac{n}{2\delta}$
13	105'-8"	100'-8"	8'-8⅞"	11.51	2510	2699	Roller-6"	945850	63.4	814,000	.860	2460	980*	.2114	4.5	.0095	2209	2442	1105	.0973	.00155	1048	856000	905	702	700	.0260	364	1274	282
14	"	"	"	"	"		"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
15	100'-0"	98'-0"	9'-5"	10.38	2055	205.4	" 4"	835100	63.9	685,200	820	2370	1150	1696	55.2	0094	1790	.1975	1134	0961	00166	0843	736560	882	776	772	0282	.435	1[illegible]	230
16	"	"	"	"	2075	2077	"	"	"	"	"	2400	1156	.1712	55.2	0095	1805	1994	"	"	"	"	"	"	780	775	"	437	1695	229
17	96'-6"	94'-2"	8'-3⅝"	11.34	1645	158.8	" 3⅝"	558510	52.4	474,800	849	2300	1398	1830	46.5	0085	1915	2147	1120	.1282	.00220	.0936	498190	892	749	732	0281	412	1505	2.45
18	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
19	91'-2"	88'-11"	9'-1¾"	9.73	2090	191.6	" 6"	776660	69.3	676,200	871	2000	958	.1305	63.3	0083	1388	1528	1100	0731	00133	0763	705210	908	8.86	8.77	0298	.523	230	191
20	83'-0"	80'-8"	9'-3"	8.72	1920	159.6	" 4"	638590	79.8	528,500	828	1970	975	.0988	79	.0078	.1066	1203	1150	0627	00127	0653	565780	886	998	982	0324	636	312	157
21	77'-6"	75'-6"	8'-5¼"	9.13	1755	136.0	Sliding	501080	67.3	431,700	862	1720	980	0883	80	.0071	0954	1063	1115	0606	00119	.0618	449470	897	1062	1048	0321	.674	353	1.48
22	70'-0"	68'-0"	7'-9¼"	8.75	1545	108.1	"	433580	60.8	361,000	833	1380	893	0590	78	0047	.0637	0698	1096	0452	00182	0554	395570	912	1312	1285	0350	900	578	111
23	64'-6"	63'-0"	6'-9¼"	9.31	1210	78.3	"	219180	54.5	181600	.829	1600	1322	0675	6.9	0046	0721	0745	1033	0616	00156	.0465	212210	968	1270	1244	037	922	572	109
24	64'-8"	62'-8"	6'-8¾"	9.30	1390	89.9	"	268840	58.1	228 200	.850	1400	1006	0620	6.8	0041	0661	0757	1145	0543	00141	0541	234800	875	1260	1232	.0360	950	628	105
25	64'-0"	61'-9"	6'-2⅝"	9.91	1250	79.8	"	194860	60.5	161,800	830	1650	1320	0724	6.2	.0045	0769	0835	1087	0668	00173	.0506	179270	920	1200	1180	.0362	.855	503	1.17
26	53'-3"	52'-0"	5'-4½"	9.69	1115	59.4	"	119000	65.6	98,500	828	1490	1336	0532	6.0	0031	0563	0615	1090	0552	00172	0412	108890	915	1398	1370	0417	1142	780	875
27	50'-0"	48'-0"	4'-7½"	10.38	1435	71.8	"	124010	55.4	103,700	836	1320	920	.0477	5.5	.0026	0503	0564	1.121	0393	.00131	0426	110620	892	1455	1405	0405	1.140	800	876
28	"	"	"	"	1395	69.8	"	"	"	"	"	1290	926	.0463	"	.0026	0489	0548	1121	"	"	"	"	"	1475	1423	"	1160	820	862
29	"	48'-4"	6'-8½"	7.23	1300	65.1	"	184620	66.5	162,600	.883	1120	862	0298	11.45	.0034	.0332	0391	1176	0300	00102	.0349	156930	850	1750	1690	0418	1413	1194	708
30	40'-0"	38'-6"	4'-0⅞"	9.45	1220	48.9	"	83040	57.3	69,300	835	950	779	.0238	6.7	0015	0253	0281	1108	0230	.00097	0295	74990	903	2065	1953	0475	1853	1620	539
31	"	"		"	"	"	"	"	"	"	"	"	"	"		"	"	"	"	"	"	"	"	"	"	"	"	"	"	"

NOTE- All spans carry one track

TABLE VI

DECK GIRDER SPANS WITH CONCRETE DECKS AND BALLASTED TRACK-OBSERVED DEFLECTION FACTORS AND DAMPING CONSTANTS

SPAN CHARACTERISTICS

Span Number	Length out to out	Length C to C of Bearings-L	Depth Overall		Span/Depth		Weight		Type of Expan. Bearing	Moment of Inertia of Section of Center					
										Gross at Center		Net at Center		Net/Gross	
			Steel Only	Steel and Deck	Steel Only	Steel and Deck	Per Ft. of Span-W Span, Deck & Track	Total of Span = W.L. (Kips)		Steel Only	Steel & Deck	Steel Only	Steel & Deck	Steel Only	Steel & Deck
32	125'-0"	122'-6"	11'-11 1/16"	11'-11 1/16"	11.04	10.27	6175	771.9	Roller	1,920,000	2,870,000	1,685,000	2,600,000	.876	.906
33	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
34	86'-6"	84'-4"	7'-11⅜ 7'-11⅛	8'-11 3/16 8'-10 15/16	10.59	9.45	7860	679.9	Roller	974,000	1,700,000	845,000	1,510,000	.868	.887
35	"	"	"	"	"	"	7960	688.5	"	"	"	"	"	"	"
36	70'-0"	67'-9"	8'-1"	9'-0 11/16"	8.65	7.48	7070	494.8	Sliding	686,000	1,296,000	597,000	1,155,000	.87	.888
37	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
38	52'-0"	50'-0" 50'-4" 50'-5	6'-7" 6'-9⅜" 6'- ⅜"	7'-8" 7'-9½" 7'-2⅞"	7.87	6.78	7100	369.2	Sliding	327,400	710,000	270,000	607,500	.825	.855
39	52'-0"	50'-4¼"	6'-9⅞"	7'-9½"	7.42	6.46	7090	368.9	Sliding	362,300	770,000	301,000	666,000	.831	865

FOR THE UNLOADED SPAN (Dead Load Only)

Span Number	Unit Stresses for Bottom Flange calculated from Net M. of I at center.				Deflections (inches)							
	For Dead Load = Sd		Per 1000 lbs per ft of Track = Sd/.001W		Calculated from Gross M. of I at Center							Observed from Tests - d
					Bending			Shear		Total-d		
	Steel Only	Steel & Deck	Steel Only	Steel & Deck	Steel Only	Steel & Deck	% of Bending	Steel Only	Steel & Deck	Steel Only	Steel & Deck	
32	5500	4820	890	780	.5630	.3771	4.9 5.7	.0276	.0216	.5906	.3987	.4406
33	"	"	"	"	"	"	"	"	"	"	"	.4368
34	4720	4040	600	510	.3166	.1814	5.3 6.2	.0168	.0112	.3334	.1927	.2262
35	4780	4090	"	"	.3207	.1837	"	.0170	.0114	.3377	.1951	.2266
36	3950	3300	560	470	.1685	.0892	8.6 10.0	.0145	.0089	.1830	.0981	.1168
37	"	"	"	"	"	"	"	"	"	"	"	.1158
38	4080	3120	570	440	.1088	.0498	10.0 12.0	.0109	.0060	.1197	.0558	.0699
39	3650	2820	510	400	.0976	.0459	10.9 12.8	.0106	.0059	.1082	0518	.0647

Span Number	Deflections (inches)					Equivalent Uniform M. of I. = Gross at Center / Deflec. Factor	Equiv. Un. M. of I. / Gross M. of I.		Natural Frequency n		Observed Damping Constant-ρ	Damping Factor Δ = 2ρn	Damping Coefficient δ = ρn²	Dynamic Magnifier K = 1/Δ = 1/2ρn
	Deflec Factor d/d		Deflection Constants											
	Steel Only	Steel & Deck	Deflection per 1000 lbs. per ft of Trk. = d/.001W	Deflection per 1000 lbs. at Center per track	Deflection per 1000 lbs Stress = d/.001Sd		Steel Only	Steel & Deck	Theoretical	Assumed				
32	.746	1.105	.07135	.000932	.0914	2,597,300	1.340	.897	5.26	5.15	.047	.484	1.246	2.07
33	.738	1.096	.07074	.000924	.0906	2,618,600	1.355	.912	5.29	5.18	.047	.487	1.261	2.05
34	.678	1.174	.02878	.000546	.0560	1,428,400	1.475	.852	7.36	7.23	.035	.506	1.829	1.98
35	.671	1.162	.02847	.000540	.0554	1,463,700	1.490	.861	7.35	7.23	.035	.506	1.829	1.98
36	.639	1.190	.01652	.000390	.0354	1,089,100	1.565	.840	10.24	9.42	.059	1.112	5.236	.90
37	.637	1.169	.01627	.000383	.0348	1,108,600	1.595	.855	10.33	9.50	.059	1.121	5.425	.89
38	.584	1.250	.00984	.000313	.0224	568,000	1.712	.800	13.36	Loaded Frequencies are too high to determine damping factors.				
39	.598	1.250	.00913	.000290	.0229	616,000	1.672	.800	13.75					

NOTE:- Deflections and deflection factors are the average for the span acting as unit.
It has been assumed for all spans that- $\frac{E_s}{E_c} = 8.0$

about the same as those with open floor, although the deflection factor might be somewhat lower due to the friction developed between the floor and girder flange.

The damping constants, p, were derived from the damping factors, Δ, found experimentally under the various test loads. The assumption that $\Delta = 2pn$, implies that all of the bridge damping decreases with an increase in the load on the span. This would be true if all of the bridge damping were proportional to velocity, or due to elastic friction in the material of which the span is built. This assumption is on the safe side, as has been explained, when estimating the impact allowance for the maximum loading, from damping factors, obtained experimentally with a lighter load. There is no doubt, but that a large portion of the damping is due to external forces, such as end bearing friction, which oppose span vibration. If this friction could be increased without introducing objectionable stresses in the span or in the bridge substructure, the dynamic deflection, and therefore the amount of impact, would be reduced. Fifty years ago, Professor Robinson[1] suggested that expansion rollers be discarded, and this suggestion may deserve serious consideration, although many of us have in the past taken every precaution to ensure the free operation of such bearings.

The values of the damping constants, as found experimentally, have been plotted in Fig. 15. It will be seen that they are a function of the span frequency or stiffness. The constants for spans 4, 6, 10 and 11, are somewhat out of line, but these spans had small and inadequate expansion bearings, and the high values of the damping constants are undoubtedly due to large end bearing friction. Span 12 would perhaps have acted in the same manner had it been carried on masonry piers instead of timber bents, which were probably flexible enough to provide for the elongation of the bottom chord under load, even though the rollers were inactive. All other spans had large expansion rollers which operated freely, and their damping constants fall on a smooth curve.

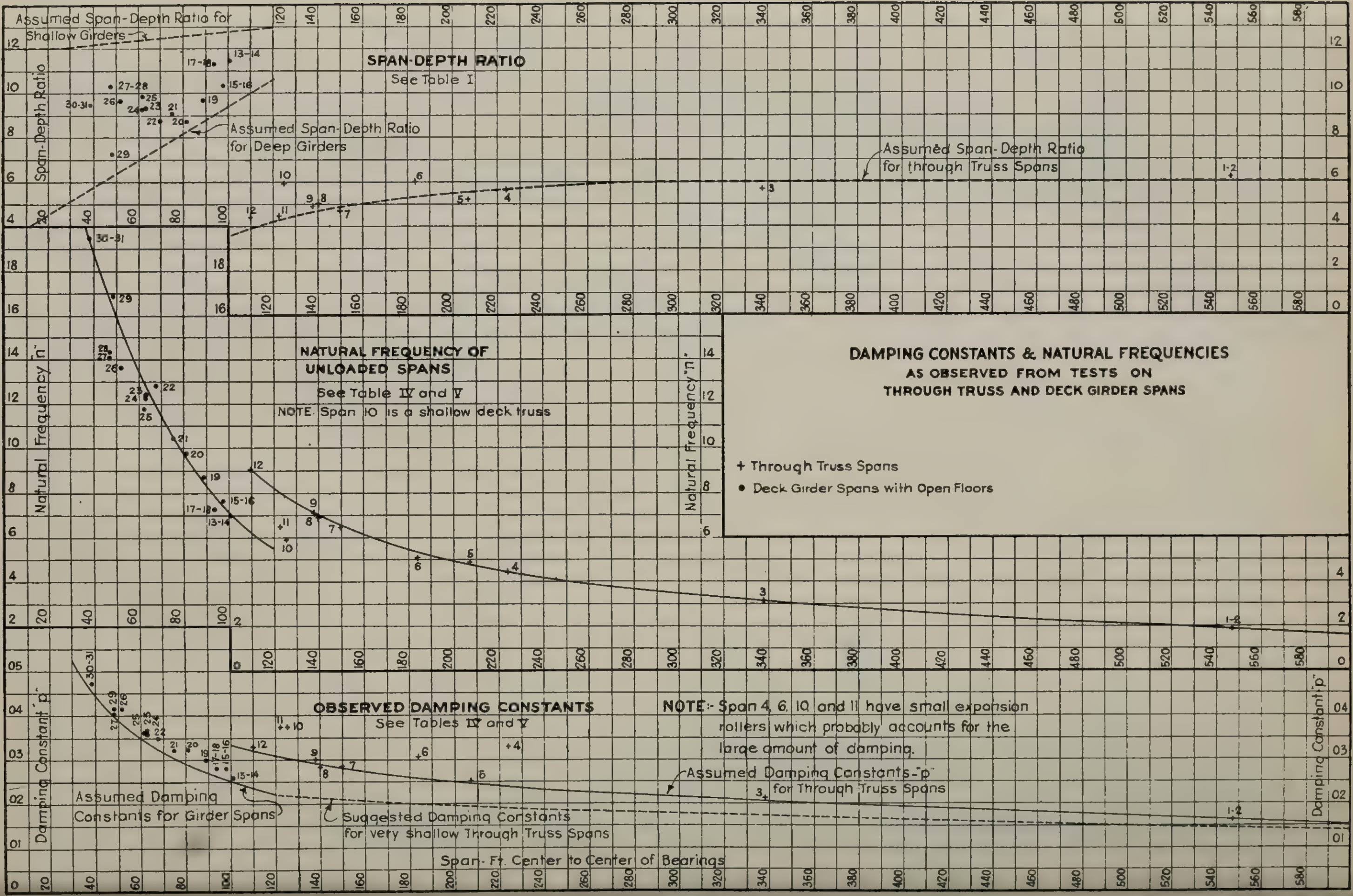
The damping constants for the girders, with open floors, are also consistent. In the upper diagram the span-depth ratios of the test spans have been plotted, and while they are generally of average depth, it will be seen that the shallow girders show slightly lower constants than deeper girders of about the same span, as was to be expected.

The results for both truss and girder spans are so uniformly in line that it would seem that the method used of deriving these constants, from measured dynamic magnifiers, is sound and that these damping constants may be safely used for estimating the amount of magnification and impact in similar spans. A line, representing the damping constants to be used, has been drawn through the lower values as found for the truss spans. The lower dotted line gives the suggested values for very shallow truss spans. For the girder spans, the line has been drawn below the lowest measured values as representing the damping to be expected in the shallowest girders. The spans which were tested were of medium span-depth ratio, and it is probable that deep girders would have a greater amount of damping, but the values given by this line should be safe for any span of this type.

The damping constants as found in the girders with solid floors are higher than those for spans with open floors. Undoubtedly a large part of this increase is due to the stiffness and high frequency of the spans tested, although some of this damping may have been due to the ballasted track. Just what damping would be found in girders on which the floor did not contribute anything to the span stiffness, is not known, as such spans were not tested.

The calculated natural frequencies, given in the tables, are the theoretical undamped frequencies of the unloaded spans, as derived from the loaded frequencies given by equation (3), that is, using the actual concentrations for the live load. Generally, the assumed frequency is the theoretical frequency, corrected for damping. In one or two of the

DAMPING CONSTANTS & NATURAL FREQUENCIES AS OBSERVED FROM TESTS ON THROUGH TRUSS AND DECK GIRDER SPANS



shorter spans, the observed frequency seemed to be slightly lower than the damped frequency, and for those spans the frequencies as found from the tests are given. These frequencies have been plotted in the middle diagram of Fig. 15, and are also shown on Fig. 21, for comparison with the unloaded frequencies of the hypothetical spans assumed for determining the impact allowance to be used in designing.

It may be said that the calculated frequencies were found in all cases, except for Span No. 12, to be in close agreement with the observed frequencies, and for all practical purposes the frequency can be expressed as, $n = \sqrt{\frac{12}{d + D}}$.

In the last three columns of Tables IV, V, VI are shown the damping factors, damping coefficients and dynamic magnifiers of the unloaded spans. They are of but little value but are given for the purpose of comparison.

(b) OBSERVED EFFECT OF TRACK AND WHEEL IRREGULARITIES

There was no definite information obtained from the tests as to the effect of low or open joints in the rails. On a few of the records, taken on short spans, there was evidence of the drivers having encountered a rail joint at the time the span was in its extreme displaced position, but such instances were too few to be of any value, and for the present nothing can be added to what has already been stated in Part V, section f.

Many tests on the shorter spans showed the dynamic effect of rough or eccentric wheels of passenger equipment, but in no case would this be the controlling factor in fixing the impact allowance, and it need not be considered.

(c) OBSERVED EFFECT OF ROLLING OR SWAYING OF LOCOMOTIVES AND CARS

In testing many of the spans, a deflectometer was placed on each truss or girder, and for such spans we have a direct measurement of the effect of rolling or transfer of load from one rail to the other. For the locomotive, it is given by the variation in the deflection *D*.

Where only one instrument was used and there are a sufficient number of tests, we can still reach a close approximation of the amount of roll by comparing the individual deflections with the average of that group.

On short spans the increase in deflection, due to rolling of the locomotive, is scarcely ever found to be more than 10 per cent, and usually not more than 5 per cent. On long spans it is less.

The tables giving the results of the tests contain no information as to the deflection under the trains, but many records were examined for evidence of car roll. Frequently some minor variations would be found, but any allowance provided for the effect of engine roll should take care of this effect from cars. If it be assumed that this action is not dynamic in its effect, it can be provided for by an increase in the static live load. The amount which finally finds its way to the girders or trusses depends upon their spacing. Committee XV tentatively recommended the simple formula, $\frac{100}{S}$, as representing the amount, in percentage, to be added to the live load, S being the distance between girders or trusses. For short girders, with the usual spacing of 6 ft. 6 in., the increase in live load would be about 15 per cent. For single track through truss or girder bridges, it would be about 5 per cent. For spans made up of several stringers or girders, as is frequently the case in solid floor bridges, the rolling force should be considered as applied at the rail ($S = 5$), and the distribution to the various girders computed.

(d) VIBRATIONS CAUSED BY FREIGHT CARS

Owing to the lack of time, it has been impossible to examine all of the records and assemble the information as to the impact caused by freight cars. On short spans, the locomotive impact should govern in all cases, but on long spans there is the possibility that the dynamic effect of the cars may exceed that of the locomotive. The tests of several truss spans have been investigated, and it is quite apparent that:

(1) Many cars pass over a bridge without causing any appreciable vibration. This may be true as to the entire train, or all but a few cars. In other trains, many if not all of the cars may set up vibrations, and the oscillations induced by a certain number of these cars become quite large. The above statements seem to apply to cars which are both lightly and heavily loaded, running at high or low speeds. This would seem to indicate that the type and design of the car, or perhaps the condition of its springs, are the controlling factors which determine the amount of impact it may produce.

(2) The frequency of the forced vibrations is dependent, partially at least, upon the amount of load the car contains. With lightly loaded cars we find frequencies of from 4.5 to 6, and with loaded cars, of from 2.0 to 3.5. Such frequencies are about in line with the calculated unloaded and loaded spring frequencies of the average car, so it would appear that the forced vibrations are caused by the oscillation of the sprung weight. There seems to be no very definite relation between the magnitude of the oscillations and ratio of the oscillation frequency to the loaded frequency of the span.

(3) Larger oscillations are found in long spans than in short spans, but, due to the smaller static deflection in the latter, the resulting impact, as expressed in terms of the live load, is greater in short spans than in long spans.

Some of the points mentioned above are illustrated in the following diagrams.

Fig. 16-a. The frequencies of the forced vibrations found in a 138 ft. through truss (Span No. 9), have been plotted in relation to the static deflection, or to the load on the span at the time the oscillations occurred. We find high frequencies for lightly loaded cars, and low frequencies for heavily loaded cars.

Fig. 16-b and 16-c. The magnitude of the oscillations, found in a 138 ft. truss (Span No. 9), and a 184 ft. truss (Span No. 6), are shown in relation to the ratio of the frequency of the oscillations to the loaded frequency of the span at the time the oscillations occurred. In the 138 ft. span the maximum oscillations appear when their frequency is from .5 to .8 of span frequency. In the 184 ft. span the maximum values are found when the oscillations have a frequency of about .9 of the span frequency. If more tests had been obtained at the other frequency ratios, it is quite probable that high values at other ratios would have been found. The evidence as to the effect of the ratio of spring frequency to span frequency on the oscillations is inconclusive, but it does show that from a certain number of cars, at least, high oscillations are found when the springs have about the same frequency as the span.

Fig. 17. The car impact, as measured in Spans Nos. 4, 6 and 9, is plotted in terms of deflection or equivalent uniform load. It will be seen that in the 138 ft. and 184 ft. trusses the impact is quite high for lightly loaded cars, and drops to 10 to 15 per cent for heavily loaded cars. In the 224 ft. truss (Span No. 4) it is much less than the increase in span length would seem to justify. This span was found to possess a high damping factor, due presumably to large end bearing friction, and it is probable that the impact values are smaller than those which might have been found, had this bridge been provided with large and freely operating expansion rollers.

In Span No. 7, a 150 ft. double track truss, which is not included in the diagram, the impact in the heavily loaded truss was found to be 40 per cent for light cars, and

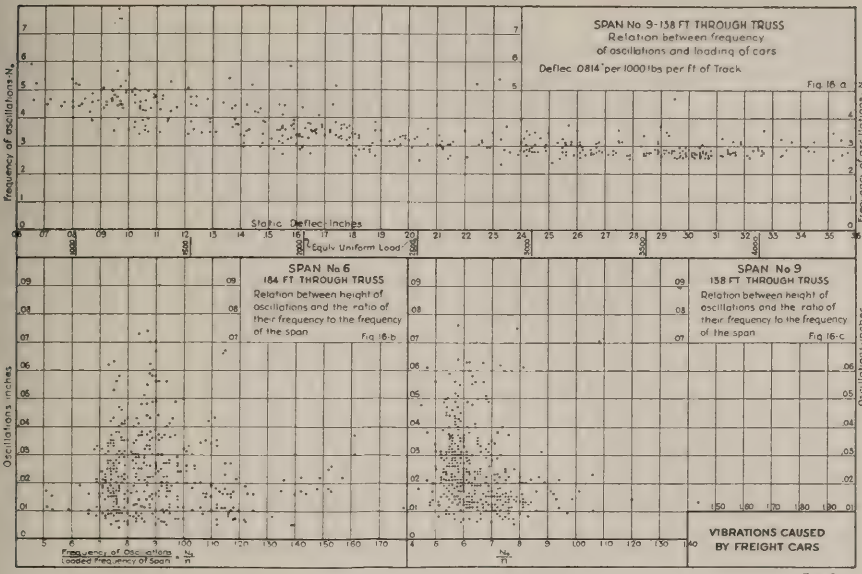

SPAN No 9 - 138 FT THROUGH TRUSS
Relation between frequency of oscillations and loading of cars
Deflec .0814" per 1000 lbs per ft of Track
Fig 16 a
Frequency of oscillations - N_o
Static Deflec - Inches
Equiv Uniform Load
SPAN No 6
184 FT THROUGH TRUSS
Relation between height of oscillations and the ratio of their frequency to the frequency of the span
Fig 16-b
SPAN No 9
138 FT THROUGH TRUSS
Relation between height of oscillations and the ratio of their frequency to the frequency of the span
Fig 16-c
Oscillations - inches
Frequency of Oscillations / Loaded Frequency of Span = $\frac{N_o}{n}$
$\frac{N_o}{n}$
VIBRATIONS CAUSED BY FREIGHT CARS

Fig 16

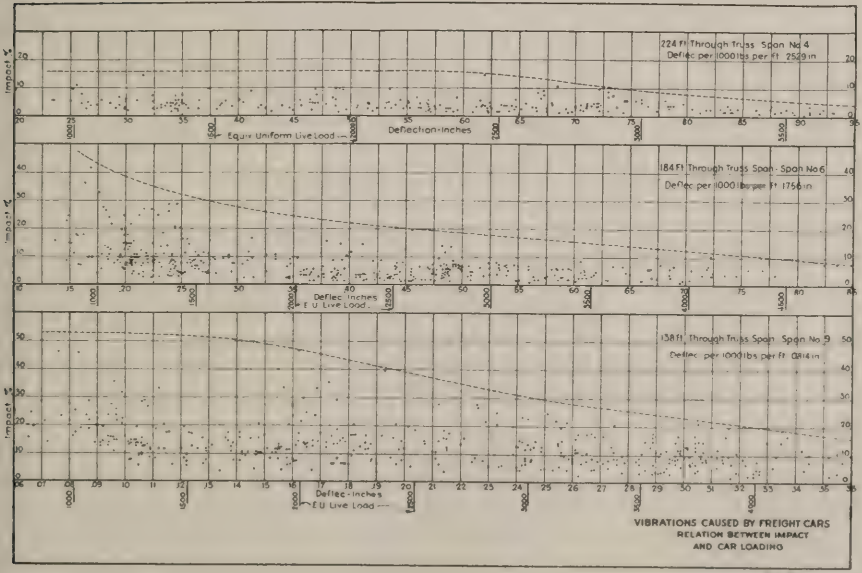

224 Ft Through Truss Span No 4
Deflec per 1000 lbs per ft .2529 in
Impact %
Equiv Uniform Live Load
Deflection - Inches
184 Ft Through Truss Span - Span No 6
Deflec per 1000 lbs per ft .1756 in
Deflec Inches
E U Live Load
138 Ft Through Truss Span - Span No 9
Deflec per 1000 lbs per ft .0814 in
Deflec - Inches
E U Live Load
VIBRATIONS CAUSED BY FREIGHT CARS
RELATION BETWEEN IMPACT AND CAR LOADING

Fig 17

18 per cent for heavy cars. In the light truss the corresponding values were 62 per cent and 27 per cent.

In all of these diagrams it will be seen that of the large number of cars causing measurable vibration, only a comparatively small number of them, due to some feature of their design or condition, produced large oscillations. It must be remembered, however, that these records represent what occurs in every 24 or 48 hours, so that these extreme oscillations occur frequently enough to be taken into account.

Unfortunately trains were not used in testing the longer spans (Nos. 1, 2 and 3), and it is on such spans that the locomotive impact is small. Until we have more information as to the effect of oscillating cars on long spans, it would be well to assume that they may produce an impact of about 15 per cent, and that this should be the minimum to be provided for such spans, even though the locomotive impact is less.

(e) Damping from the Locomotive Springs

In Part V, the effect of locomotive spring damping on spans of intermediate length, Case II, was discussed, and in Fig. 9 the theoretical effect of this damping on an 80 ft. span was illustrated, using two values for spring friction.

In many of the spans between 40 and 150 ft. in length, it was found that the oscillations caused by certain locomotives did diminish in magnitude, about as predicted by the theory of spring damping. This will be seen on several of the diagrams in Appendix B. We can not expect to find a very close agreement between the theoretical and actual values. The theoretical oscillations, as determined by the equations given, are based on the assumption that damping results from the action of the locomotive springs only, while the tender and car springs, if they are vibrating, should contribute additional damping. By referring to Fig. 9 it will be seen that the amount of spring friction has a marked effect on the magnitude of the oscillations, and this friction must vary a great deal between locomotives, even when they are of like design. It would depend upon the condition of the bearings of the equalizing levers, and also upon the amount of friction between the journal-boxes and their guides. This latter friction may in turn depend upon the heat generated in the journals, and may be larger when the engine is working than when it is drifting.

We have no positive proof that spring action did take place on any span, but the growth and later diminution of the oscillations in certain structures, can best be accounted for by the assumption that they were damped by spring friction. Accepting this explanation, it can be said that when such damping did take place, the spring friction was rarely found to be less than 10 per cent, nor more than 15 per cent of the sprung weight. In estimating the maximum oscillation or amount of impact under this condition, Case II, the lower value should be used as will be apparent by reference to Fig. 9. The value assigned for the frequency of the spring vibration is not so important. The calculated spring frequencies of the locomotives, used in the tests, are given in Table XIV, Appendix A.

For some unknown reason, the springs of certain individual locomotives, or of all locomotives used on some bridges, apparently remained locked, although the oscillations were of such character that a reasonable amount of spring friction should have been overcome. This was the case in Spans No. 9 and No. 12, as shown in Fig. 45 and 51 of Appendix B, and it points out the necessity of investigating spans of intermediate length for the two conditions; Case I, assuming that the springs remain locked, and Case II, that they become active. The maximum estimated impact, as determined by either one of these two conditions, should be used.

(VII) ESTIMATING THE AMOUNT OF IMPACT IN EXISTING BRIDGES

One of the most troublesome problems, confronting the Bridge Engineer, is that of passing upon the load carrying capacity of some of his older structures of light design, in which the amount of impact to be allowed for is the deciding factor. The method of estimating impact which has been outlined is well suited to this purpose, as it takes into account the characteristics of the particular locomotive and span with which he is dealing. For the purpose of illustrating the application of this method, several typical spans will be analyzed.

(a) A Short Span

Let us take a 20 ft. span, consisting of two beams under each rail, with no transverse bracing between the pairs of beams, as shown in Fig. 18. The beams have a uniform M. of I. throughout their length, so that we may use a deflection factor of 1.00. The shear deflection will be about 6 per cent of that due to bending, which gives the following deflection constants:

For 1000 lb. per ft. per rail.............................. .02202 in.
For 1000 lb. at the center, per rail......................... .00175 in.

It will be supposed that we wish to determine the amount of impact resulting from the use of an H7-E, Type IV locomotive. From Table XIV, we find that the wheel loads, *R*, are 31,350 lb., and that the individual driver hammer blows, *Q*, at 1 r.p.s., are 479, 386, 386 and 490 lb. Inasmuch as the beam groups are directly under the rail, and are not connected by cross bracing, they will deflect independently of one another, so that we must use the wheel, rather than the axle, hammer blows.

Placing the drivers in the position of maximum moment for the static load, and the center of gravity of the individual hammer blows at the center of the span, we find that the equivalent central load which will produce the same deflection is 72,290 lb. for the wheels, and 969 lb. for the hammer blow. Using the deflection constant of .00175, for

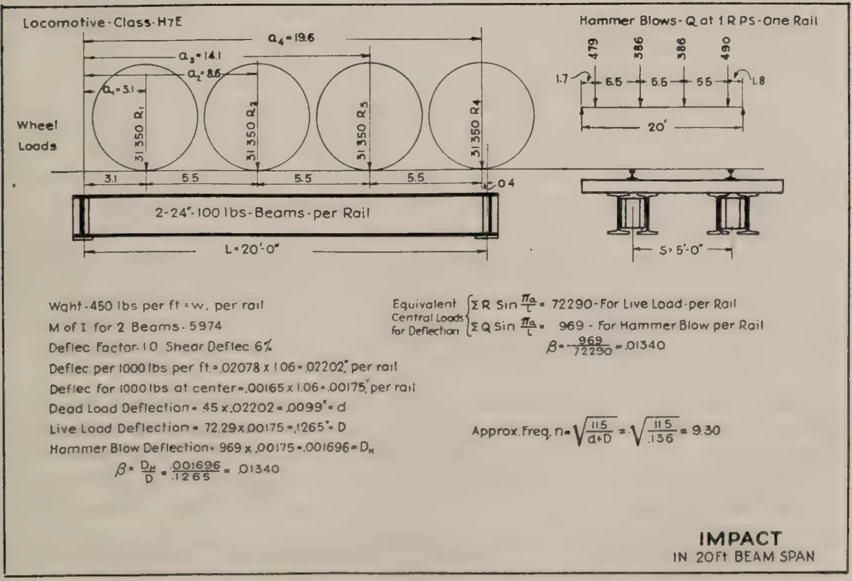

Locomotive-Class-H7E
$a_4 = 19.6$
$a_3 = 14.1$
$a_2 = 8.6$
$a_1 = 3.1$
Wheel Loads
31 350 R_1
31 350 R_2
31 350 R_3
31 350 R_4
3.1
5.5
5.5
5.5
.04
2-24"-100 lbs-Beams-per Rail
L = 20'-0"
Hammer Blows-Q at 1 RPS-One Rail
479
386
386
490
1.7
6.5
6.5
5.5
1.8
20'
S = 5'-0"
Wght-450 lbs per ft = w, per rail
M of I for 2 Beams-5974
Deflec Factor-1.0 Shear Deflec 6%
Deflec per 1000 lbs per ft. = .02078 x 1.06 = .02202" per rail
Deflec for 1000 lbs at center = .00165 x 1.06 = .00175" per rail
Dead Load Deflection = .45 x .02202 = .0099" = d
Live Load Deflection = 72.29 x .00175 = .1265" = D
Hammer Blow Deflection = 969 x .00175 = .001696 = D_H
$\beta = \frac{D_H}{D} = \frac{.001696}{.1265} = .01340$
Equivalent Central Loads for Deflection
$\Sigma R \sin \frac{\pi a}{L} = 72290$ - For Live Load per Rail
$\Sigma Q \sin \frac{\pi a}{L} = 969$ - For Hammer Blow per Rail
$\beta = \frac{969}{72290} = .01340$
Approx. Freq. $n = \sqrt{\frac{11.5}{d+D}} = \sqrt{\frac{11.5}{.136}} = 9.30$
IMPACT
IN 20 Ft BEAM SPAN

Fig. 18

1000 lb. at the center, the static live load deflection, D, is .1265 inch and the static deflection, D_h, due to the hammer blow operating at 1 r.p.s., is .001696 inch. The ratio of the hammer blow to the live load, β, is $\frac{.001696}{.1265} = .0134$. The dead load deflection, d, is .0099 inch.

This span should have a natural frequency higher than any possible engine speed, but to make an approximation, without using the more complicated formula (3), we may say that the loaded frequency $n = \sqrt{\frac{11.5}{d + D}} = 9.30$. We find that synchronism cannot occur, and for this condition it has been shown that the dynamic magnifier is unity or less, so that the hammer blow can be considered as a static force, and the locomotive impact is simply βN^2. The engines of this particular class seem incapable of attaining a speed of much over 5 r.p.s., or 56.5 m.p.h., and at that speed the impact in percentage of the live load is $100 \beta N^2 = 100 \times .0134 \times 25 = 33.5$ per cent. The low joint impact is $\frac{325}{L} = 16.3$ per cent, and the increase in live load due to roll is $\frac{100}{S} = 20$ per cent, making a total of 69.8 per cent. Had this been a passenger locomotive, with the same proportion, β, of hammer blow to weight, and capable of a speed of 7 r.p.s., its impact would be $100 \times .0134 \times 49 = 65.7$ per cent, and the total impact would be $65.7 + 16.3 + 20 = 102$ per cent.

We might have selected an H10-A, Type I, locomotive, which has practically the same static effect, but whose individual wheel hammer blows are only 281, 263, 86 and 268 lb. The equivalent central load is 474 lb., and the β, for this engine is .00655, which is about one-half of that for the H7-E, and its impact effect would be one-half as large. Had this span been of light design, it is quite evident that full information as to the counterbalancing of the locomotives to be used and the speed at which they were to be operated would be most useful in fixing its load carrying capacity. If it were just strong enough for the operation of the H10-A locomotive at 5 r.p.s., with a total impact of $16.5 + 16.3 + 20 = 52.8$ per cent, the H7-E engine could be operated only at such a speed that its impact did not exceed $52.8 - (16.3 + 20) = 16.5$ per cent, or at a speed of 3.45 r.p.s.

(b) A Span of Intermediate Length

We will assume a deck girder 100 ft. long, 98 ft. between bearings, and a Class J1-D locomotive with a partially loaded tender, as shown in Fig. 19. The span is so short that the train weight need not be considered.

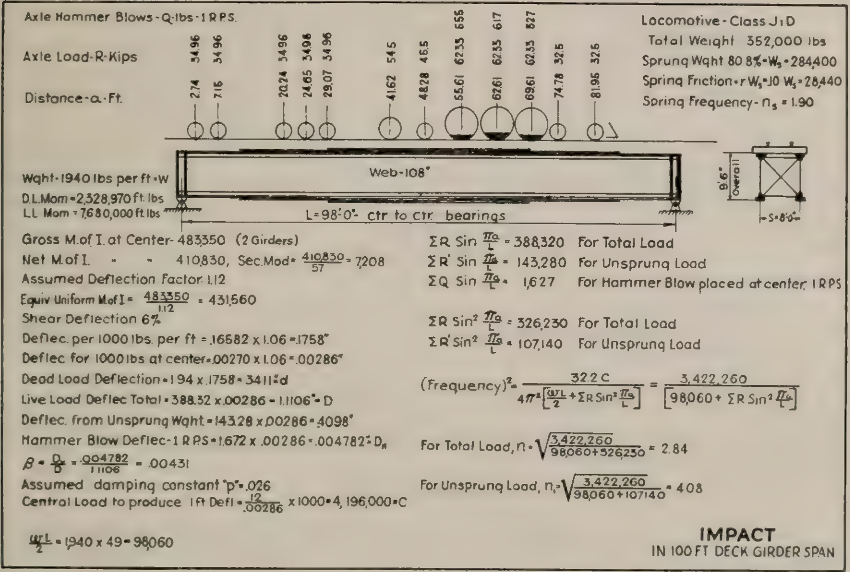
The gross M. of I. at the center for both girders is 483,350. From Table V we find that the deflection factor should be about 1.12, giving an equivalent uniform M. of I. of 431,560. Using this value in the usual deflection formula, and adding shear deflection, we obtain the following constants:

Central deflection for 1000 lb. per ft. per track....	.1758 in.
Central deflection for 1000 lb. at center, per track.........	.00286 in.

Inasmuch as these girders are rigidly connected to one another, we may use the axle hammer blows which are, at 1 r.p.s., 527, 617 and 555 lb. We find that the equivalent central load, for the entire weight of the locomotive and tender is 388,200 lb., and that for the hammer blow is 1627 lb. β is .00431; and the live load deflection, D, is 1.1106 in.

We will first investigate this span for Case I, assuming that the locomotive springs remain locked and inactive. The loaded frequency, n, from equation (3) which takes into account the wheel concentration, is found to be 2.84. The synchronous speed is 2.84 r.p.s. which for this locomotive is 40.04 m.p.h.

From Fig. 15 we see that the damping constant, p, for a span of this length is .026. The impact from the locomotive, when its springs are inactive, is $\frac{\beta n}{2p}$, or in percentage of the live load, it is $\frac{100 \times .00431 \times 2.84}{.052} = 23.5$ per cent. The live load deflection, D, being 1.1106, the oscillation, h, is $1.1106 \times .235 = .261$ inch. If such an oscillation will overcome the friction of the locomotive springs, it will be necessary to investigate this span for Case II. Assuming the low spring friction of 10 per cent of the sprung weight, that is $r = .10$, the magnitude of the oscillation, having a frequency of 2.84, which will just overcome this amount of friction, is $\frac{r}{.1022 N^2} = \frac{.10}{.1022 \times 2.84^2} = .121$ inch. Evidently spring friction may be overcome, and it is necessary to determine what the impact will be at the second and higher synchronous speed, resulting from the oscillation of the sprung weight.



Gross M.of I. at Center- 483350 (2 Girders)

Net M.of I. " " 410,830, Sec.Mod $= \frac{410,830}{57} = 7,208$

Assumed Deflection Factor 1.12

Equiv Uniform M.of I $= \frac{483350}{1.12} = 431,560$

Shear Deflection 6%

Deflec. per 1000 lbs. per ft = .16582 x 1.06 = .1758"

Deflec for 1000 lbs at center = .00270 x 1.06 = .00286"

Dead Load Deflection = 1.94 x .1758 = .3411" = d

Live Load Deflec Total = 388.32 x .00286 = 1.1106" = D

Deflec. from Unsprung Wght = 143.28 x .00286 = .4098"

Hammer Blow Deflec-1 R.P.S = 1.672 x .00286 = .004782" = D_H

$\beta = \frac{D_H}{D} = \frac{.004782}{1.1106} = .00431$

Assumed damping constant "p" = .026

Central Load to produce 1 ft Defl $= \frac{12}{.00286} \times 1000 = 4,196,000 = C$

$\frac{wL}{2} = 1940 \times 49 = 98,060$

$\Sigma R \sin\frac{\pi a}{L} = 388,320$ For Total Load

$\Sigma R' \sin\frac{\pi a}{L} = 143,280$ For Unsprung Load

$\Sigma Q \sin\frac{\pi a}{L} = 1,627$ For Hammer Blow placed at center, 1 RPS

$\Sigma R \sin^2\frac{\pi a}{L} = 326,230$ For Total Load

$\Sigma R' \sin^2\frac{\pi a}{L} = 107,140$ For Unsprung Load

$$(\text{Frequency})^2 = \frac{32.2\,C}{4\pi^2\left[\frac{wL}{2} + \Sigma R \sin^2\frac{\pi a}{L}\right]} = \frac{3,422,260}{\left[98,060 + \Sigma R \sin^2\frac{\pi a}{L}\right]}$$

For Total Load, $n = \sqrt{\frac{3,422,260}{98,060 + 326,230}} = 2.84$

For Unsprung Load, $n_1 = \sqrt{\frac{3,422,260}{98,060 + 107140}} = 4.08$

IMPACT
IN 100 FT DECK GIRDER SPAN

Fig. 19

Of the engines of this class, 80.8 per cent of the total weight is spring borne, and the natural frequency, n_1, of the span when carrying the tender and unsprung weight of the locomotive is 4.08. The calculated spring frequency, n_s, is 1.90. Substituting the known values, $n = 2.84$, $n_1 = 4.08$, $n = 1.90$, and taking the larger root of the quadratic equation, $f^4 - f^2 n_1^2\left(1 + \frac{n_s^2}{n^2}\right) + n_1^2 n_s^2 = O$, we find that the second and higher frequency, f, is 4.61.

The deflection, D_h, due to the hammer acting statically at the center, is .000396 ft. Assuming the spring friction to be 10 per cent of the sprung weight ($r = .10$), we find from the equation, $\Theta = \frac{p\,(f^2 - n_s^2)}{12.27\,D_h\,f^4 - \frac{f^2 - n^2}{n^2}}$, that Θ, the locomotive spring damping coefficient, at f (4.61) r.p.s., is .8015.

The impact in percentage of the live load is obtained from the equation, Impact, per cent $= 100 \times \dfrac{r \sqrt{(f^2 - n_s^2)^2 + (2f\Theta)^2}}{D \,.\, 2.454 f^3 \Theta}$. Substituting the known values, we find that maximum amount of impact to be expected when the locomotive springs are free and active is 10.8 per cent. With the springs locked, Case I, the impact was found to be 23.5 per cent, and this value should be used, as occasionally for some reason spring action, or at any rate spring damping, does not take place, although the oscillations may be large enough to overcome a reasonable amount of spring friction. This will be seen on several of the diagrams in Appendix B.

The impact due to track inequalities may be taken as $\frac{325}{98} = 3.3$ per cent, and the increase in live load, due to roll, is $\frac{100}{8} = 12.5$ per cent, giving a total of 39.3 per cent. The section modulus of this span is 7208, and the calculated unit flange stress is:

Dead Load		3,880	
Static Live Load		12,780	
Loc. Impact	$.235 \times 12780$	3,000	
Track "	$.033 \times 12780$	410	
Rolling	$.125 \times 12780$	1,600	21,670

If this span were in good condition, there would be no question as to its capacity for this particular loading at any speed, the critical speed being 40 m.p.h. By the recently discarded impact formula, which ignores the engine and span characteristics and speed, the estimated impact would be $\frac{30{,}000}{30{,}000 + 98^2} = 76$ per cent, and the calculated stress would be:

Dead Load		3,880	
Static Live Load		12,780	
Impact—	$.76 \times 12780$	9,710	26,370

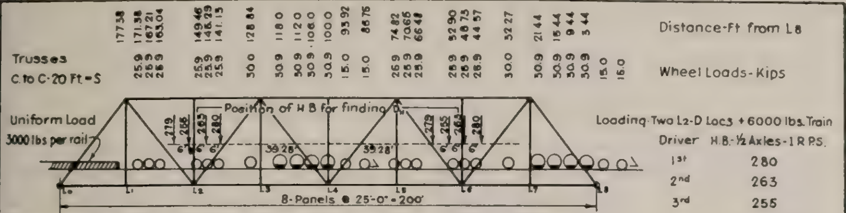
Such a stress, in a bridge carrying high speed traffic, would be a source of worry to many Engineers, and it is not unlikely that a needless expense for its renewal or strengthening might have been incurred.

(c) A Long Span

We will take as an example of this type a 200 ft. eight-panel through truss, as shown in Fig. 20.

The panel point deflection coefficients give the theoretical deflection, in inches, contributed to the central deflection, by a load of 1000 lb. at that panel point on each truss. A deflection factor of .80 is assumed. The live load consists of two L2-D locomotives followed by a uniform load of 6000 lb. per ft. Each locomotive has a hammer blow of 2154 lb. at 1 r.p.s. In computing the hammer blow deflection, D_h, the engines are placed symmetrically about the center of the span as shown in the diagram.

From the calculated panel loads, we find that the dead load deflection, d, is .4704 inch; the live load deflection, D, is .8702 inch, and the hammer blow deflection, D_h, is .002646 inch. The loaded frequency, n, is 2.99, and β is .00304; the damping constant, p, should be about .025, as shown in Fig. 15. The locomotive impact is $100 \times \frac{\beta n}{2p} = \frac{100 \times .00304 \times 2.99}{.050} = 18.2$ per cent. The distance between trusses being 20 ft., the increase in live load, due to roll, is 5.0 per cent. The low joint impact is too small to take into account.



Loading-Two L2-D Locs + 6000 lbs. Train

Driver	H.B.-½ Axles-1 R.P.S.	
1st	280	
2nd	263	
3rd	255	
4th	279	1077

Panel Loads per Truss-kips							
D.L.	47.3	47.5	47.7	47.9	47.7	47.5	47.3
L.L.	74.10	91.93	84.51	97.52	78.71	90.09	89.48
H.B.	.094	.811	.172		.168	.825	0.84

Central Deflection for Loads at various Panel Points-One Truss Deflec. Factor=1.00

1000 lbs. at	Coefficient	D.L. Defl. d	L.L. Defl. D	H.B. Defl. D_H
L1	.000750	.03548"	.05558"	.000070"
L2	.001457	.06921	.13394	.001181
L3	.002330	.11114	.19691	.000401
L4	.003265	.15639	.31840	
L5	.002330	.11114	.18339	.000391
L6	.001467	.06921	.13244	.001202
L7	.000750	.03548	.06711	.000063
		.58805"	1.08777"	.003308"
Deflec. Factor		0.8	0.8	0.8
True Deflection		.4704"	8702"	.002646"

Assumed Damping Constant-p = .025

Weight of Span and Deck per ft = 3800 lbs

Deflec. per 1000 lbs per ft. $= \frac{.4704}{38} = .1237"$

Deflec. for 1000 lbs. at Center $= \frac{.003265}{2} \times 0.8 = .001306"$

Loaded Frequency $n = \sqrt{\frac{12}{d+D}} = \sqrt{\frac{12}{1.341}} = 2.99$ $\beta = \frac{D_H}{D} = \frac{.002646}{.8702} = .00304$

Locomotive Impact $= 100 \times \frac{\beta n}{2p} = \frac{304 \times 2.99}{.05} = 18.2\%$

Low Joint Effect .0

Increase in Live Load for Roll $= \frac{100}{S} = \frac{100}{20} = 5.0\%$

IMPACT
IN 200 Ft THROUGH TRUSS SPAN

Fig. 20

(d) Impact in Floor Beams

Floor beams usually are so deep, and so rigidly connected, that their natural frequency is too high for synchronism to occur at any possible engine speed. Therefore they may be treated as short spans, and the hammer blow of the locomotive be considered as acting statically. As an illustration we will take one of the floor beams of the span shown in Fig. 20.

The static live load floor beam reaction, from one rail, is 107,700 lb., and that from the hammer blow, with the engine in the same position, is 815 lb.; then $\beta = \frac{815}{107{,}700} = .00757$. With a maximum engine speed, N, of 7 r.p.s., the locomotive impact is $100\,\beta N^2 = 37.1$ per cent. If there were a rail joint directly over the beam, its effect might be taken as equivalent to a force of $250\,N^2 = 12{,}250$ lb., and its impact, in percentage of the live load, would be $100 \times \frac{12{,}250}{107{,}700} = 11.4$ per cent. The increase in live load, due to roll is, $\frac{100}{20} = 5.0$ per cent. The total increase in static load being, $37.1 + 11.4 + 5.0 = 53.5$ per cent.

Shallow transverse I-beams in solid floor bridges, may have relatively low frequencies, but even on such members the locomotive hammer blow may be considered as a static force, as no beam can receive more than one application of this force. With drivers having a circumference of 20 ft., and the beams, 2 ft. 6 in. apart, the counterweight on any driver would be in its lowest position at every eighth beam. A low joint directly over a beam might contribute impulses which synchronized with the beam frequency, resulting in some magnification, but when this effect is large, that from the hammer blow is small. As an extreme case, assume that the beam has a frequency of 7, and that the drivers are 7 ft. center to center. For low joint synchronism, the locomotive would have a velocity of 49 f.p.s., or a speed of 2.4 r.p.s. But the hammer blow at this speed is low, being only $\frac{2.4^2}{7.0^2}$, or about .12 of its maximum at 7 r.p.s.

(e) Floor Beam Hangers and Columns

In nearly all such members the locomotive hammer blow may be considered as a static force without magnification. A vertical rod carrying a weight, *W*, which produces an elongation of *e*, inches, has a natural frequency of vibration, *n*, in a longitudinal direction, as expressed by $\sqrt{\frac{9.8}{e}}$. With a modulus of elasticity of 29,000,000, the elongation per ft. length of rod, when it is stressed to an intensity of 1000 lb. per sq. in., is .000414 inch. In the truss shown in Fig. 20, we have found that the total impact in the floor beam is 53.5 per cent. With a total unit stress of 18,000 lb., and a dead load stress of 1500 lb., the permissible unit static stress is $\frac{16,500}{1.535} + 1500 = 12,250$ lb. The effective length of the verticals in this truss is about 25 ft., so that the elongation, of any one of the hangers under static load would be $.000414 \times 25 \times 12.25 = .1368$ inch, and its natural frequency would be 8.25. This, of course, is too high for synchronism at any possible locomotive speed, and if synchronism should occur, the panels, being but little more than a driver circumference in length, are so short that but one effective application of the hammer blow could be delivered.

The same line of reasoning may be used in the investigation of posts and columns. The worst condition would obtain in a high viaduct. Columns 80 ft. long and having a unit static stress of 12,000 lb., would shorten about .407 inch, and have a frequency of about 4.9. This is within the range of locomotive speeds, although such a speed, 55 to 70 m.p.h., would be unusual over a structure of this type. However, if the columns were designed for the same amount of impact as found for the short tower spans, the contingency of any possible magnification of the hammer blow, when the locomotives were on the longer intermediate spans, would be provided for.

(f) Impact at Reduced Speed

In the preceding examples the maximum locomotive impact has been used, that is, the impact occurring at synchronous speed. At any other speed, the impact is

$$\frac{\beta N^2}{\sqrt{\left(1-\frac{N^2}{n^2}\right)^2 - (2p\,N)^2}},$$

in which N is the speed of the locomotive in r.p.s., and *n*, the natural loaded frequency of the span. The term in the denominator, of the above expression, will be recognized as the reciprocal of the dynamic magnifier *k*—(see equation 19) and from Fig. 8 it will be seen that a slight change either way from synchronous speed results in a large reduction in magnification, especially when the amount of damping is small. As $\frac{N}{n}$ becomes small the value of k approaches unity, regardless of the amount of damping, and as N becomes small, the numerator decreases rapidly so that we may expect to find very little impact at low speeds, and light bridges can frequently be retained in service at reduced speed, when such a restriction is not too objectionable. But in establishing this reduced speed, consideration must be given to the synchronous speed. On a 500 ft. span the critical speed may be only 12 m.p.h. and for this span half speed would be 6 m.p.h. On a short girder the critical speed might be 70 m.p.h. and half speed in this case would be 35 m.p.h.

(VIII) IMPACT ALLOWANCE FOR DESIGNING

The method of computing the amount of impact in existing spans, as illustrated in the preceding chapter, may be used for the determination of an impact allowance for designing new bridges. For some particular locomotive and train it is necessary to select some imaginary loading which will produce the maximum static and dynamic effect to be expected during the life of the structure. And instead of dealing with spans of known section, we must assume spans of such section that they will not be stressed beyond a certain specified limit by any application of the selected live load. Given the assumed live load and the sections of the spans, the two problems are quite similar.

(a) Assumed Loading

For this study there has been assumed a group of axle loads as shown in Table VII, and which is designated as the A-72 loading. The actual intensity of the loading is not so important, but the spacing, arrangement, relative axle loads, and the dynamic augment should represent as closely as possible actual locomotives and cars. For this reason, the A loading has been selected rather than the Cooper E loading, as the locomotive weight is proportionately larger, and the train weight smaller.

The principal dynamic effect of the two cylinder steam locomotive, is due to the rotation of the weights which are placed on the drivers for the purpose of counterbalancing the inertia of a portion of the reciprocating parts. If this were not done, the engine would have a tendency to oscillate, to an objectionable extent, in a horizontal plane. It is this excess counterweight which produces the hammer blow, and as its effect on track and bridge structures is directly proportional to the amount of the overbalance, and increases with the square of the speed, it is important that it be no larger than is necessary to assure satisfactory operation of the locomotive. A portion of each counterweight is provided to balance the rotating parts, such as the connecting rods, crank pins, etc., but inasmuch as these are in balance for any position of the wheel, they are not harmful. In the three cylinder locomotive, on which the crank pins are set at 120°, the reciprocating parts balance themselves to a large extent, and such engines and electric locomotives can be considered as smoothly rolling loads.

The weight of the reciprocating parts, which include the piston, piston rod, crosshead shoe, and the front half of the main rod, bears quite a definite relation to the total weight of the locomotive, the weight of these parts on one side being usually from $\frac{1}{150}$ to $\frac{1}{200}$ of the total. It will be seen in Table XIV of Appendix A that for the engines used in the tests, this proportion had an extreme range of from $\frac{1}{159}$ to $\frac{1}{216}$, but for most of the locomotives it varied only from $\frac{1}{170}$ to $\frac{1}{190}$. It is customary to balance about 50 per cent of the reciprocating parts, although on the test engines this proportion varied from 20.5 per cent to 58 per cent. It would seem therefore that for the purpose of fixing the amount of hammer blow to be used with the selected static live load, we might safely assume that the weight of reciprocating parts on one side will not exceed $\frac{1}{175}$ of the weight of the locomotive, and that 50 per cent of this weight will be counterbalanced.

The weight of the locomotive being 480,000 lb., the weight of the reciprocating parts on one side would be 2740 lb. To counterbalance 50 per cent of this weight, it would be necessary to provide a weight of 1370 lb. at crank pin radius on each side of the locomotive. It will be assumed that this weight is distributed equally over four drivers, or

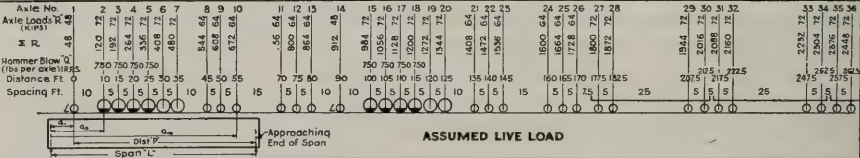
342 lb. per wheel. With a crank pin radius of 15 in., the centrifugal force or hammer blow produced by these weights, when rotating at 1 r.p.s., is 525 lb. per wheel.

On bridges with adequate transverse bracing the two girders or trusses act in unison, so that the resultant axle, rather than the wheel, hammer blow need only be considered. The crank pin on one side of the engine usually leads that on the other by 90°, so that the maximum axle effect occurs when the counterweight on one side is 45° past, and that on the opposite side is within 45° of the lowest position. The hammer blow per axle is $525 \times 1.414 = 742$ lb., and for the entire locomotive it is 2968 lb. The even figures of 750 lb. and 3000 lb. at 1 r.p.s. have been used. Short spans, of 10 or 20 ft. in length, may not have cross bracing, and the two stringers or girders may act independently. On such spans the wheel hammer blow of 525 lb. per stringer should be used, instead of one-half of the axle hammer blow, which is 375 lb.

Table VII gives the spacing and axle weights, *R*, of the assumed loading, and the position for maximum moment, on spans from 10 to 575 ft. in length. Placing the load in this position, the equivalent central load, which would produce the same central deflection as the several concentrations, is $\Sigma R \, Sin \frac{\pi a}{L}$. For the purpose of obtaining the hammer blow deflection, D_h, the individual axle hammer blows, *Q*, except on the 10 and 20 ft. spans, are placed symmetrically about the center, and the equivalent central load for the hammer blow deflection is $\Sigma Q \, Sin \frac{\pi a}{L}$. On spans more than 135 ft. in length, the hammer blow from the second engine is taken into account, the center of gravity of each group being equally spaced about the center of the span. The ratio of the hammer blow deflection to the live load deflection is $\beta = \dfrac{\Sigma Q \, Sin \frac{\pi a}{L}}{\Sigma R \, Sin \frac{\pi a}{L}}$, and the amount of impact is

TABLE VII

ASSUMED LIVE LOAD AND SPAN CHARACTERISTICS


Axle No. 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Axle Loads "R" (KIPS) 48 72 72 72 72 72 72 64 64 64 64 64 64 48 72 72 72 72 72 72 64 64 64 64 64 64 72 72 72 72 72 72 72 72 72 72
Σ R 48 120 192 264 336 408 480 544 608 672 .56 800 864 912 984 1056 1128 1200 1272 1344 1408 1472 1536 1600 1664 1728 1800 1872 1944 2016 2088 2160 2232 2304 2876 2448
Hammer Blow "Q" (lbs per axle) 1 R.P.S. 750 750 750 750 750 750 750 750
Distance Ft. 0 10 15 20 25 30 35 45 50 55 70 75 80 90 100 105 110 115 120 125 135 140 145 160 165 170 177.5 182.5 207.5 212.5 217.5 222.5 247.5 252.5 257.5 262.5
Spacing Ft. 10 5 5 5 5 5 10 5 5 15 5 5 10 10 5 5 5 5 5 10 5 5 15 5 5 7.5 5 25 5 5 5 25 5 5 5
a₁
a₂
aₙ
Dist "P"
Span "L"
Approaching End of Span
ASSUMED LIVE LOAD

DECK GIRDER SPANS - OPEN FLOOR

Span "L" Feet C to C Bearing	DEEP			SHALLOW			Dist "P" for Live Load	EQ. UN. LIVE LOAD		Equiv Central Concentration for Live Load $\Sigma R \, Sin \frac{\pi a}{L}$	Equiv Central Concentration for Hammer Blow $\Sigma Q \, Sin \frac{\pi a}{L}$	$\frac{\text{Hammer Blow Deflec}}{\text{Live Load Deflec}} \frac{\Sigma Q \, Sin \frac{\pi a}{L}}{\Sigma R \, Sin \frac{\pi a}{L}} = \frac{D_H}{D} = \beta$
	Depth-Inches Overall	$\frac{\text{Span}}{\text{Depth}}$	Weight of Span per ft w including track	Depth-Inches Overall	$\frac{\text{Span}}{\text{Depth}}$	Weight of Span per ft w including track		For Moments $W_M = \frac{8 \, Mom.}{L^2}$	For Deflection $W_D = \frac{16 \Sigma R \, Sin \frac{\pi a}{L}}{L}$			
10	30.0	4.0	1000	10.0	12.0	1100	18.7	16200	15220	95100	1387	.01458
20	53.3	4.5	1290	20.0	12.0	1390	26.2	14850	15090	188600	2750	.01458
30	70.6	5.1	1370	29.8	12.1	1480	36.2	14600	14700	275800	2510	.009101
40	84.2	5.7	1460	39.4	12.2	1590	41.2	13580	13560	339000	2718	008018
50	95.2	6.5	1570	48.8	12.3	1710	51.6	12640	12460	389400	2818	.007237
60	104.4	6.9	1710	58.0	12.4	1850	55.0	12220	12100	453700	2874	.006335
70	112.0	7.5	1850	67.2	12.5	2000	62.0	11710	11570	506300	2906	.005740
80	118.5	8.1	2020	76.2	12.6	2170	149.5	11250	11050	552300	2928	.005302
90	124.1	8.7	2210	85.0	12.7	2340	154.5	10960	10820	608500	2943	.004837
100	129.0	9.3	2420	93.8	12.8	2530	164.0	10650	10460	654000	2955	.004518
120	137.1	10.5	2880	110.8	13.0	2920	177.5	10240	10150	761700	2968	.003897

NOTE-Assumed Hammer Blow per engine is 3000 lbs at 1 R.P.S.-distributed equally on four axles, or "P"= 750 lbs per axle at 1 R.P.S.

For Spans 20 ft and less in length, with no cross bracing assume a hammer blow of 525 lbs per wheel acting independentally on each stringer.

In computing hammer blow deflections, "D_H," for 1 R.P.S. the distributed hammer blow is assumed as acting statically at the center of the span.

In computing Live load deflections "D," the load is assumed to be in the position producing maximum moment, wheel No. 1 being "P" from approaching end of span

SINGLE TRACK THROUGH TRUSS SPANS - OPEN FLOOR

Span "L" Feet C to C Bearings	Depth-Feet C to C Chords	$\frac{\text{Span}}{\text{Depth}}$	Weight of Span per ft w including track	Distance "P" for Live Load	EQ. UN. LIVE LOAD		Equiv Central Concentration for Live Load $\Sigma R \, Sin \frac{\pi a}{L}$	Equiv Central Concentration for Hammer Blow $\Sigma Q \, Sin \frac{\pi a}{L}$	$\frac{\text{Hammer Blow Deflec}}{\text{Live Load Deflec}} \frac{\Sigma Q \, Sin \frac{\pi a}{L}}{\Sigma R \, Sin \frac{\pi a}{L}} = \frac{D_H}{D} = \beta$
					For Moments $W_M = \frac{8 \, Mom}{L^2}$	For Deflections $W_D = \frac{16 \Sigma R \, Sin \frac{\pi a}{L}}{L}$			
100	28	3.57	2600	164	10650	10460	654020	2954	.004518
120	28	4.23	2700	177.5	10240	10100	757640	2968	.003897
145	31	4.68	3050	186.5	9900	9880	895660	2977	.003731
170	33	5.16	3410	197.0	9660	9700	1030280	2984	.003903
195	36	5.42	3790	201.0	9650	9770	1190880	4472	.003755
225	40	5.63	4270	218.0	9650	9600	1350200	4840	.003585
255	43	5.93	4750	237	9380	9440	1504830	5090	.003382
[illegible]	48	6.05	5330	262	9140	9120	1652340	5292	.003203
325	54	6.02	5900	288	8900	8890	1805270	5433	.003009
360	60	6.00	6490	314	8670	8690	1954960	5536	.002833
400	67	5.98	7170	350	8440	8490	2123420	5624	.002649
440	73	6.03	7870	389	8250	8340	2294720	5688	.002479
485	81	5.99	8650	421	8080	8160	2472080	5758	.002327
530	89	5.97	9420	465	7930	8060	2669270	5788	.002167
575	96	5.99	10200	510	7820	7990	2870634	5818	.002067

All Spans are assumed as Carbon Steel

directly proportional to this ratio. On the 10 and 20 ft. spans, the wheel hammer blows of 525 lb. have been assumed as acting on each girder, and inasmuch as there is no magnification of the hammer blow effect on spans of this length, β may be taken as the ratio of wheel hammer blow to wheel weight, or $\frac{525}{36000} = .01458$.

The impact allowance is based on a maximum speed of 7 r.p.s., which would correspond to a speed of about 99 m.p.h. for a passenger locomotive having 79 in. drivers, and 79 m.p.h. for a freight locomotive having 63 in. drivers. While such speeds are unusual at the present time, they are sometimes attained, and should be provided for.

(b) ASSUMED SPANS

Deck girders ranging in length from 10 to 120 ft., and through trusses from 100 to 575 ft. long, have been selected as typical spans for this investigation. All spans are assumed to be of carbon steel with open floors, and carrying a single track. Inasmuch as the amount of impact depends upon the natural loaded frequency of the span, or upon its stiffness, girders of two kinds have been considered: deep girders having high frequencies, with span-depth ratios varying from 4.0 for the 10 ft. span, to 10.5 for the 120 ft. span, and shallow girders having low frequencies, with the corresponding span-depth ratios of 12.0 to 13.0. The depths of the short through truss spans are fixed by the overhead clearance, so that the span-depth ratio for the 100 ft. span is only 3.6, but following common practice, this ratio is gradually increased until a value of 6.0 is reached for a span about 275 ft. in length, and for all of the longer spans a depth of 1/6 of the length is used.

The sections of these spans must be such that under the dead load, static live load, locomotive and low joint impact, and the rolling or lurching effect, the total unit stress will not exceed the basic designing stress, which has been assumed as 18,000 lb. per sq. in. Definite values can be assigned in advance for all of these forces except that resulting from locomotive hammer blow. It has been shown (equation 22) that the locomotive impact, as long as its springs remain inactive, is $\frac{\beta n}{2p}$, in which n, the frequency, is very nearly equal to $\sqrt{\frac{12}{d+D}}$, or the amount of impact may be expressed as, $\frac{1.73\beta}{p} \times \sqrt{\frac{1}{d+D}}$. From this expression, it is seen that the amount of impact depends upon the deflection, but the deflection depends upon the section, and the section depends upon the amount of impact, so that, to arrive at the required section, it is necessary to resort to a "cut-and-try" process, but two or three trials are usually sufficient. The values for the damping constant, p, were taken from the curves given in Fig. 15. The same amount of damping has been used for both sets of girders, although the deep spans should have somewhat higher damping constants, giving less impact, than the shallow spans. Unfortunately we have not enough information at this time to justify any greater refinement. The experimental values were obtained largely from spans having medium span-depth ratios, but the constants used should be safe for shallow girders, and be somewhat conservative for deep girders.

(c) ESTIMATED IMPACT FOR THE ASSUMED SPANS

The sections of the spans were first determined for Case I, that is, with the locomotive springs locked, after which the spans were investigated for Case II, with the springs acting. If, under this second condition of loading, the stress was found to exceed 18,000 lb., the sections were increased and the impact for Case I recomputed. After the sections were thus finally determined, calculations were made to find what increase in loading, with its corresponding impact, would be permissible for an allowable unit stress of 26,000 lb. It was assumed that the hammer blow would increase proportionately with the live load, that is, that β would remain unchanged, and of course the damping constant, p, is the same for any condition of loading.

Weights, moments, deflection constants, deflections, frequencies and dynamic magnifiers, as found for the various spans, are given in Tables VIII, IX and X.

The estimated impact for Cases I and II, and for unit stresses of 18,000 lb. and 26,000 lb., are given in Tables XI, XII and XIII. It was found that Case II governed for quite a range in span lengths, the increase being considerable, especially in the shallow girders, as shown in the following table:

Type of Span	*Lengths for which Case II Governs*	*Max. Increase of Case II over Case I*	
		Increase	*Span Length*
Deep Girder Spans			
18,000 lb. stress	67 ft. to 94 ft.	33%	81 ft.
26,000 " "	56 " " 93 "	50%	71 "
Shallow Girder Spans			
18,000 lb. stress	46 ft. to 86 ft.	49%	63 ft.
26,000 " "	33 " " 83 "	67%	56 "
Through Truss Spans			
18,000 lb. stress	100 ft. to 113 ft.	11%	100 ft.
26,000 " "	100 " " 103 "	7%	100 "

The increase in the amount of impact for Case II over Case I, in through truss spans, is so small that it may be neglected on such structures.

While the ultimate working stress of 26,000 lb. is 1.444 times the designing stress of 18,000 lb., we find that, without exceeding a stress of 26,000 lb., the load on girder spans may be increased from 44 to 62 per cent, and on truss spans from 59 to 98 per cent. A large part of this increase is of course due to the increase in the permissible dead load stress, but part of it may be credited to the smaller impact at the higher stress, as the more heavily loaded spans have lower frequencies. It is for this reason that we also find less impact in the shallow, low frequency girders than in the deep high frequency spans of equal length and similarly loaded.

In Fig. 21 are shown the computed undamped natural frequencies for the three conditions of loading, that is, unloaded, the A-72 loading producing 18,000 lb. stress, and the increased load which would result in a 26,000 lb. stress. It will be seen that the deep spans have higher frequencies than the shallow spans, and that the frequencies become lower with an increase in load. The impact at synchronous speed, Case I, is $\frac{\beta n}{2p}$, so that the amount of impact varies directly with the frequency, n, as long as β and p remain unchanged. We may expect then to find smaller impacts at the higher stresses and in the shallower spans. The natural frequency of a 100 ft. through truss, when loaded to produce a stress of 12,000 lb., would be about three times that of a 100 ft. shallow girder when stressed to 26,000 lb. This comparison is made to again point out the fallacy of measuring the amount of impact in a lightly loaded, deep stiff span, and assuming that the same amount of impact, even with the same relative amount of hammer blow, as expressed by β, will occur in a shallow heavily loaded span of equal length. This erroneous assumption has given us impact formulas which produce extravagant designs for many span lengths, and which afford but little more than a guess as to the amount of impact in an existing structure, loaded approximately to its capacity.

TABLE VIII

ASSUMED CHARACTERISTICS OF DEEP DECK GIRDER SPANS WITH OPEN FLOOR

Length of Span-L	Depth overall inches	$\frac{Span}{Depth}$	Dead Load per ft · ω (lbs)	Moments 1000 ft lbs		Equivalent Uniform Moment of Inertia	Deflec for 1000 lbs at center including Shear (inches)	Equiv Central Loads for Deflec - Kips			Deflection Inches			$\beta = \frac{D_H}{D} = \frac{\Sigma Q \sin\frac{\pi a}{L}}{\Sigma R \sin\frac{\pi a}{L}}$	Damping Constant p	Frequency n			Dynamic Magfr $K = \frac{1}{2pn}$		
				Dead Load	Live Load A·72			Dead Load $\frac{\omega L}{16}$	L L · A · 72 $\Sigma R \sin\frac{\pi a}{L}$	Hammer Blow $\Sigma Q \sin\frac{\pi a}{L}$	Dead Load d	Live Load A-72 D	Hammer Blow at 1 R P S D_H			Dead Load	Total Stress 18000 lbs	Total Stress 26000 lbs	Dead Load	Total Stress 18000 lbs	Total Stress 26000 lbs
10	300	40	1000	125	2025	4610	000369	63	951	1387	0023	0351	.000512	.01458		7303	1856	1544		100	100
20	533	45	1290	645	7425	28570	000452	161	1886	2750	0073	.0853	001243	01458		4128	1164	969		100	100
30	706	51	1370	154.1	16425	80000	.000520	257	2758	2510	.0133	.1434	001305	009101	0520	3046	893	736	32	100	131
40	842	57	1460	2920	27169	151800	.000620	365	3390	2718	0226	.2103	.001686	008018	0445	2340	714	580	48	157	194
45	900	60	1520	3848	33002	192000	.000688	428	3622	2773	0295	2493	001909	007656	.0415	2051	649	528	.59	186	228
50	952	63	1570	4906	39492	236100	.000756	491	3894	2818	.0371	.2945	002132	.007237	.0390	1827	593	483	.70	216	265
55	1000	66	1640	620.1	47027	287100	.000819	564	420.0	2850	.0462	3438	002333	006786	.0370	1639	550	449	.82	246	301
60	1044	69	1710	769.5	54994	342200	.000883	641	4537	2874	.0566	.4005	002537	006335	.0350	1480	511	419	.97	280	341
65	1083	72	1780	940.1	63363	398800	.000954	723	4820	2892	.0690	.4598	.002759	.006000	0335	1341	475	389	111	314	384
70	1120	75	1850	11331	71738	475900	.000990	80.9	5063	2906	.0801	.5012	002877	.005740	0315	1244	452	3.65	128	3.52	434
75	1154	78	1940	1364.1	80604	557700	.001032	909	5279	2920	.0938	.5445	003012	.005531	.0305	1150	430	345	143	381	475
80	1185	81	2020	16160	90003	646500	001073	1010	5523	2928	.1083	.5923	003141	.005302	.0290	1070	411	327	161	419	5.26
85	1214	84	2120	19146	100224	733500	.001127	1126	5808	2937	.1269	.6546	.003310	.005057	.0280	989	393	314	181	454	569
90	1241	87	2210	22376	111023	784700	.001244	1243	608.5	2.943	.1546	.7570	.003661	.004837	.0270	895	364	296	207	5.09	625
95	1267	90	2320	2617.3	121542	858200	.001332	1378	6282	2949	.1836	.8368	003928	004694	.0260	822	347	2.86	234	554	671
100	1290	93	2420	3025.0	133140	951000	.001396	1613	6540	2955	.2112	.9130	.004120	.004518	.0250	766	325	269	2.61	615	744
110	1333	99	2640	3993.0	158163	1154300	.001518	181.5	7092	2962	.2755	1.0766	.004496	.004177	.0235	671	298	246	3.17	714	865
120	1371	10.5	2880	5184.0	184785	1388800	.001627	216.0	761.7	2968	.3514	12393	.004829	.003897	.0220	5.94	275	228	3.83	826	9.97

NOTE The Frequencies and Dynamic Magnifiers given above are based on the assumption that the locomotive springs remain locked The Dynamic Magnifiers are for synchronous speed

TABLE IX

ASSUMED CHARACTERISTICS OF SHALLOW DECK GIRDER SPANS WITH OPEN FLOOR

Length of span-L (feet)	Depth overall (inches)	$\frac{Span}{Depth}$	Dead Load per ft ω (lbs)	Moments 1000 ft lbs		Equivalent Uniform Moment of Inertia	Deflec for 1000 lbs at center including Shear (inches)	Equiv Central Loads for Deflec (Kips)			Deflection (inches)			$\beta = \frac{D_H}{D} = \frac{\Sigma R \sin\frac{\pi a}{L}}{\Sigma Q \sin\frac{\pi a}{L}}$	Damping Constant p	Frequency n			Dynamic Mag'fr $K = \frac{1}{2pn}$		
				Dead Load	Live Load A-72			Dead Load $\frac{\omega L}{16}$	L L · A-72 $\Sigma R \sin\frac{\pi a}{L}$	Hammer Blow $\Sigma Q \sin\frac{\pi a}{L}$	Dead Load d	Live Load A-72 D	Hammer Blow at 1 R P S D_H			Dead Load	Total Stress 18000 lbs	Total Stress 26000 lbs	Dead Load	Total Stress 18000 lbs	Total Stress 26000 lbs
10	100	1200	1100	13.8	202.5	1540	000804	69	951	1387	.0058	.0799	.001165	.01458		4625	12.26	1021		1.00	100
20	20.0	12.00	1390	695	742.5	10750	000962	17.4	1886	2.750	.0167	.1814	.002646	.01458		2722	7.96	662		1.00	100
30	29.8	1210	1480	1665	1642.5	30900	.001129	27.8	2758	2510	.0314	.3114	.002834	.009101	0520	1988	605	492	.48	1.59	1.95
35	346	1215	1540	2358	2179.5	46300	.001196	337	3136	2666	.0403	.3751	.003183	.008501	.0480	1754	5.43	443	.59	192	235
40	394	1220	1590	3180	2716.9	64300	.001285	398	3390	2718	.0511	.4356	.003492	008018	0445	1557	494	404	.72	227	278
45	44.1	1225	1650	4177	33002	86000	.001369	464	362.2	2773	.0635	4959	.003796	.007656	.0415	1397	457	375	86	263	321
50	488	1230	1710	5344	39492	113900	.001416	534	3894	2.818	.0756	5514	.003990	.007237	.0390	1281	431	350	1.00	297	3.66
55	534	1235	1780	6731	47027	160000	.001431	612	420.0	2850	0876	.6010	.004078	.006786	.0370	1189	414	332	114	326	407
60	580	1240	1860	8325	54994	193900	001437	694	4537	2.874	0997	.6520	.004130	.006335	.0350	1115	3.99	3.15	128	358	4.53
65	626	1245	1975	10430	63363	240300	.001474	802	4820	2892	.1182	7105	.004263	006000	.0335	1024	380	300	1.46	393	498
70	672	1250	2000	12250	7173.8	284100	.001557	875	5063	2906	.1362	.7878	.004525	.005740	.0315	954	351	285	1.66	452	557
75	718	1255	2085	14660	80604	331700	.001639	977	527.9	2920	.1601	.8652	.004786	.005531	.0305	880	3.39	274	186	484	5.98
80	76.2	12.60	2170	1736.0	90003	385900	.001710	108.5	5523	2.928	.1855	.9444	.005007	.005302	0290	818	324	264	211	534	654
85	806	1265	2260	20411	100224	446200	001772	120.1	5808	2937	.2128	1.0292	.005204	.005057	0280	763	312	256	234	572	697
90	850	1270	2340	23693	111023	511000	.001837	1316	608.5	2943	2418	11178	.005406	.004837	0270	716	298	246	259	621	753
95	894	1275	2440	27526	121547	589300	.001873	1449	6282	2949	.2714	11766	.005523	004694	0260	676	286	237	285	672	812
100	938	1280	2530	31625	133140	677700	001899	1581	6540	2955	.3002	12420	.005612	004518	0250	643	278	230	311	720	871
110	102.3	12.90	2720	41140	158163	872200	001962	1870	7092	2962	3669	13915	005811	.004177	.0235	581	261	217	3.66	815	980
120	1108	13.00	2920	52560	184785	1108000	.002005	2190	7617	2968	4391	1.5272	.005951	003897	.0220	531	247	205	428	919	1108

NOTE · The Frequencies and Dynamic Magnifiers given above are based on the assumption that the locomotive springs remain locked The Dynamic Magnifiers are for Synchronous speed.

TABLE X

THROUGH TRUSS SPANS - SINGLE TRACK - OPEN FLOOR - CARBON STEEL

Span-Ft. C to C. of Bearings	Depth-Ft. C. to C. of Chords	$\frac{\text{Span}}{\text{Depth}}$	Load per ft. of Span			Net Chord Section-□" Per Span	Deflection-per 1000 lbs. per ft. inches	Deflection (inches)			$\beta = \frac{D_H}{D}$	Damping Constants $p = \frac{\delta}{n^2}$	Freq. $n = \sqrt{\frac{12}{d+D}}$			Dynamic Magnifier $K = \frac{1}{\Delta} = \frac{1}{2pn}$		
			Dead Load w	E.U.L.L.-A72 For Moment	E.U.L.L.-A72 For Deflec			For Dead Load d	For Live Load A-72 D_H	H. Blow at 1 RPS D_H			Dead Load	A-72 Loading Total Stress 18000 lbs.	Total Stress 26000 lbs.	Dead Load	18000 lbs Unit Stress	26000 lbs Unit Stress
100	28	3.57	2600	10650	10460	44.3	.037	.096	.387	.00175	.004518	.0332	1118	498	4.03	135	303	374
120	28	4.23	2700	10240	10100	58.3	.052	.140	.525	.00206	.003897	.0308	9.24	4.25	3.48	175	3.82	4.66
145	31	4.68	3050	9900	9880	749	.072	.220	.711	.00265	.003731	.0285	7.38	359	2.98	2.38	4.86	588
170	33	5.16	3410	9660	9700	96.4	.092	.314	.892	.00348	.003903	.0267	6.18	3.15	2.62	3.03	5.95	7.15
195	36	5.42	3790	9650	9770	117.2	.109	.413	1.065	.00400	.003755	.0251	5.38	2.85	2.38	3.70	6.99	8.36
225	40	5.63	4270	9650	9600	143.2	.130	.556	1248	.00447	.003585	.0237	4.64	2.58	2.14	4.55	818	9.86
255	43	5.93	4750	9380	9440	170.7	.150	.713	1.416	.00479	.003382	.0228	4.10	2.37	1.97	5.35	9.25	11.18
290	48	6.05	5330	9140	9120	2003	.172	.917	1.569	.00494	.003203	.0218	3.62	2.19	1.83	6.34	10.47	12.53
325	54	6.02	5900	8900	8890	223.7	.192	1.135	1.707	.00519	.003009	.0208	3.24	2.05	1.71	7.42	1172	14.05
360	60	6.00	6490	8670	8690	2503	.209	1.356	1.816	.00514	.002833	.0201	2.98	1.94	1.62	8.40	12.82	15.35
400	67	5.98	7170	8440	8490	282.1	.228	1.635	1.936	.00513	.002649	.0194	2.72	1.83	1.53	9.48	14.08	16.84
440	73	6.03	7870	8250	8340	320.5	.246	1.935	2.052	.00504	.002479	.0186	2.49	1.73	1.45	10.80	15.53	18.53
485	81	5.99	8650	8080	8160	360.0	.263	2280	2.146	.00500	.002327	.0176	2.29	1.65	1.38	12.41	17.21	2058
530	89	5.97	9420	7930	8060	403.1	.278	2.615	2.241	.00486	.002167	.0166	2.14	1.57	1.32	14.08	19.16	22.82
575	96	5.99	10200	7820	7990	455.1	.291	2.965	2.325	.00471	.002067	.0156	2.00	1.50	1.27	16.03	21.37	25.24

NOTE:- The Frequencies and Dynamic Magnifiers given above are based on the assumption that the locomotive springs remain locked. The Dynamic Magnifiers are for synchronous speed.

TABLE XI

IMPACT ALLOWANCE FOR DEEP GIRDER SPANS WITH OPEN FLOOR

Length-L ft.	Depth overall (inches)	$\frac{\text{Span}}{\text{Depth}}$	Low Joint	Impact in Percentage of Live Load — A-72 Loading - 18000 lb. Stress						Impact in Percentage of Live Load — A72 (1.45 to 1.62) 26000 lb. Stress						Increase in A-72 Loading for 26000 lb Stress	
				Case I Springs Locked Freq. n	Case I Springs Locked Imp %	Case II Springs Free Freq. f	Case II Springs Free Imp. %	Total Case I	Total Case II	Case I Springs Locked Freq. n.	Case I Springs Locked Imp %	Case II Springs Free Freq. f	Case II Springs Free Imp. %	Total Case I	Total Case II	Case I	Case II
10	30.0	4.0	30.3	18.56	◤71.3			◤101.6		15.44	◤71.3			◤101.6		1.46	
20	58.3	4.5	16.5	11.64	◤71.3			◤87.8		9.69	◤71.3			◤87.8		1.46	
30	70.6	5.1	11.2	8.93	◤71.3			◤82.5		7.36	◤64.4			◤75.6		1.52	
40	84.2	5.7	7.8	7.14	◤64.3	14.10	35.0	◤72.1	42.8	5.80	◤52.2	12.26	35.8	◤60.0	43.6	1.57	
45	90.0	6.0	6.5	6.49	◤59.8	12.77	35.0	◤66.3	41.5	5.28	◤48.7	11.20	36.2	◤55.2	42.7	1.57	
50	95.2	6.3	5.5	5.93	◤55.0	11.50	35.4	◤60.5	40.9	4.83	◤44.8	10.13	37.2	◤50.3	42.7	1.57	
55	100.0	6.6	4.5	5.50	◤50.5	10.29	36.3	◤55.0	40.8	4.49	◤41.2	9.08	39.9	◤45.7	44.4	1.56	
60	104.4	6.9	3.5	5.11	◤46.3	9.15	38.8	◤49.8	42.3	4.19	37.9	8.16	◤43.2	41.4	◤46.7	1.56	◤1.51
65	108.3	7.2	3.0	4.75	◤42.5	8.33	41.6	◤45.5	44.6	3.89	34.8	7.54	◤46.6	37.8	◤49.6	1.56	◤1.45
70	112.0	7.5	2.5	4.52	41.1	7.77	◤45.4	43.6	◤47.9	3.65	33.3	7.04	◤49.1	35.8	◤51.6	1.61	◤1.45
75	115.4	7.8	2.3	4.30	39.0	7.43	◤46.7	41.3	◤49.0	3.45	31.2	6.74	◤47.0	33.5	◤49.3	1.65	◤1.49
80	118.5	8.1	2.0	4.11	37.6	7.09	◤47.9	39.6	◤49.9	3.27	29.9	6.41	◤41.7	31.9	◤43.7	1.68	◤1.55
85	121.4	8.4	1.8	3.93	35.5	6.77	◤46.0	37.3	◤47.8	3.14	28.3	6.10	◤33.5	30.1	◤35.3	1.68	◤1.62
90	124.1	8.7	1.5	3.64	32.4	6.17	◤36.2	33.9	◤37.7	2.96	26.4	5.62	◤28.5	27.9	◤30.0	1.61	◤1.59
95	126.7	9.0	1.3	3.47	◤31.4	5.74	31.2	◤32.7	32.5	2.86	◤25.9	5.23	23.7	◤27.2	25.0	◤1.57	
100	129.0	9.3	1.0	3.25	◤29.4	5.32	24.1	◤30.4	25.1	2.69	◤24.3	4.90	19.5	◤25.3	20.5	◤1.57	
110	133.3	9.9	0.5	2.98	◤26.5	4.71	19.3	◤27.0	19.8	2.46	◤21.9	4.36	7.8	◤22.4	8.3	◤1.58	
120	137.1	10.6	.0	2.75	◤24.4	4.28	6.8	◤24.4	6.8	2.28	◤20.2			◤20.2		◤1.58	

◤ - Maximum Case I or Case II

TABLE XII
IMPACT ALLOWANCE FOR SHALLOW GIRDER SPANS WITH OPEN FLOOR

Length-L. Ft.	Depth overall (inches)	Span / Depth	Impact in Percentage of Live Load															Increase in A-72 Loading for 26000 lb. Stress	
			Low Joint	A-72 Loading 18000 lb. Stress						A-72 (1.44 to 1.70) Loading 26000 lb Stress									
				Case I Springs Locked		Case II Springs Free		Total		Case I Springs Locked		Case II Springs Free		Total			
				Freq. n	Imp. %	Freq. f	Imp. %	Case I	Case II	Freq. n	Imp. %	Freq. f	Imp. %	Case I	Case II	Case I	Case II
10	10.0	12.0	30.3	12.26	◤71.3			◤101.3		10.21	◤71.3			101.3		◤1.46	
20	20.0	12.0	16.5	7.96	◤71.3			◤87.8		6.62	◤71.3			87.8		◤1.46	
30	29.8	12.10	11.2	6.05	◤53.0	12.08	38.9	◤64.2	50.1	4.92	◤43.1	10.63	40.0	54.3	51.2	◤1.56	
35	34.6	12.15	9.3	5.43	◤48.1	10.95	38.8	◤57.4	48.1	4.43	39.3	9.72	◤40.7	48.6	◤50.0	1.55	◤1.44
40	39.4	12.20	7.8	4.94	◤44.5	10.01	39.8	◤52.3	47.6	4.04	36.5	8.95	◤42.5	44.3	◤50.3	1.55	◤1.44
45	44.1	12.25	6.5	4.57	◤42.2	9.30	41.7	◤48.7	48.2	3.75	34.6	8.37	◤44.4	41.1	◤50.9	1.55	◤1.45
50	48.8	12.30	5.5	4.31	40.0	8.59	◤43.3	45.5	◤48.8	3.50	32.5	7.74	◤46.6	38.0	◤52.1	1.58	◤1.45
55	53.4	12.35	4.5	4.14	38.0	7.99	◤45.4	42.5	◤49.9	3.32	30.5	7.36	◤49.4	35.0	◤53.9	1.63	◤1.45
60	58.0	12.40	3.5	3.99	36.1	7.35	◤48.7	39.6	◤52.2	3.15	28.5	6.72	◤48.3	32.0	◤51.8	1.69	◤1.49
65	62.6	12.45	3.0	3.80	34.0	6.84	◤48.2	37.0	◤51.2	3.00	26.9	6.21	◤39.6	29.9	◤42.6	1.70	◤1.56
70	67.2	12.50	2.5	3.51	32.0	6.38	◤43.2	34.5	◤45.7	2.85	26.0	5.80	◤34.6	28.5	◤37.1	1.68	◤1.58
75	71.8	12.55	2.3	3.39	30.8	6.11	◤37.5	33.1	◤39.8	2.74	24.8	5.62	◤30.5	27.1	◤32.8	1.63	◤1.57
80	76.2	12.60	2.0	3.24	29.6	5.85	◤33.5	31.6	◤35.5	2.64	24.1	5.41	◤27.1	26.1	◤29.1	1.60	◤1.57
85	80.6	12.65	1.8	3.12	28.2	5.64	◤29.6	30.0	◤31.4	2.56	23.1	5.25	◤23.8	24.9	◤25.6	1.58	◤1.57
90	85.0	12.70	1.5	2.98	◤26.6	5.29	24.0	◤28.1	25.5	2.46	◤22.0	4.95	18.5	◤23.5	20.0	◤1.56	
95	89.4	12.75	1.3	2.86	◤25.8	4.96	18.8	◤27.1	20.1	2.37	◤21.4	4.65	13.1	◤22.7	14.4	◤1.57	
100	93.8	12.80	1.0	2.78	◤25.1	4.75	15.1	◤26.1	16.1	2.30	◤20.8	4.46	9.3	◤21.8	10.3	◤1.57	
110	102.3	12.90	.5	2.61	◤23.2	4.31	7.20	◤23.7	7.70	2.17	◤19.3	4.09	2.8	◤19.8	3.3	◤1.56	
120	110.8	13.0	.0	2.47	◤21.9			◤21.9		2.05	◤18.2			◤18.2		◤1.58	

◤ -Maximum Case I or Case II

TABLE XIII
IMPACT ALLOWANCES FOR THROUGH TRUSS SPANS WITH OPEN FLOOR AND OF CARBON STEEL

Span-Feet C. to C. of Bearings	Depth-Feet C. to C. of Chords	Span / Depth	Locomotive Impact in Percentage of Live Load									Permissable increase in A-72 Loading for 26000 lb Stress	
			Low Joint effect	A-72 Loading-18000 lb. Stress				A-72 (1.59 to 1.98) 26000 lb. Stress					
				Case I Springs Inactive		Case II Springs Active		Case I Springs Inactive		Case II Springs Active			
				Freq. n	Imp. %	Freq. f	Imp. %	Freq. n	Imp. %	Freq. n	Imp %	Case I	Case II
100	28	3.57	0	4.98	34.0	6.97	◤37.4	4.03	27.4	6.09	◤29.4	1.63	◤1.61
120	28	4.23	0	4.25	◤26.9	5.71	24.9	3.48	◤22.2	5.04	15.9	◤1.59	
145	31	4.68	0	3.59	◤23.3	4.68	13.7	2.98	◤19.5	3.68	10.2	◤1.59	
170	33	5.16	0	3.15	◤23.2			2.62	◤19.2			◤1.61	
195	36	5.42	0	2.85	◤21.3			2.38	◤17.8			◤1.63	
225	40	5.63	0	2.58	◤19.6			2.14	◤16.2			◤1.65	
255	43	5.93	0	2.37	◤19.6			1.97	◤14.6			◤1.67	
290	48	6.05	0	2.19	◤16.1			1.83	◤13.4			◤1.69	
325	54	6.02	0	2.05	◤14.8			1.71	◤12.4			◤1.73	
360	60	6.00	0	1.94	◤13.7			1.62	◤11.4			◤1.76	
400	67	5.98	0	1.83	◤12.5			1.53	◤10.4			◤1.79	
440	73	6.03	0	1.73	◤11.5			1.45	◤9.7			◤1.84	
485	81	5.99	0	1.65	◤10.9			1.38	◤9.1			◤1.89	
530	89	5.97	0	1.57	◤10.1			1.32	◤8.6			◤1.94	
575	96	5.99	0	1.50	◤9.9			1.27	◤8.4			◤1.98	

◤ -Maximum Case I or Case II

The unloaded frequencies, as computed from the observed loaded frequencies of the spans tested, are also shown on this diagram.

In Fig. 22 are shown the computed values of the dynamic magnifier, k, of the assumed spans, for Case I, at synchronous speed. The values are given for the unloaded bridge, for the A-72 loading (18,000 lb. stress) and for the increased load producing a 26,000 lb. stress. It will be seen that the amount of magnification is greater in shallow spans than in deep spans, and that the magnification increases with an increase in load. We have found that $k = \frac{1}{\Delta}$, and have assumed that $\Delta = 2pn$. If p is a constant, k must become larger as n becomes smaller. Due to the larger amount of end bearing friction which may be present under the heavier load, the amount of magnification may not actually increase at the rate shown, but the assumption which has been made is on the safe side.

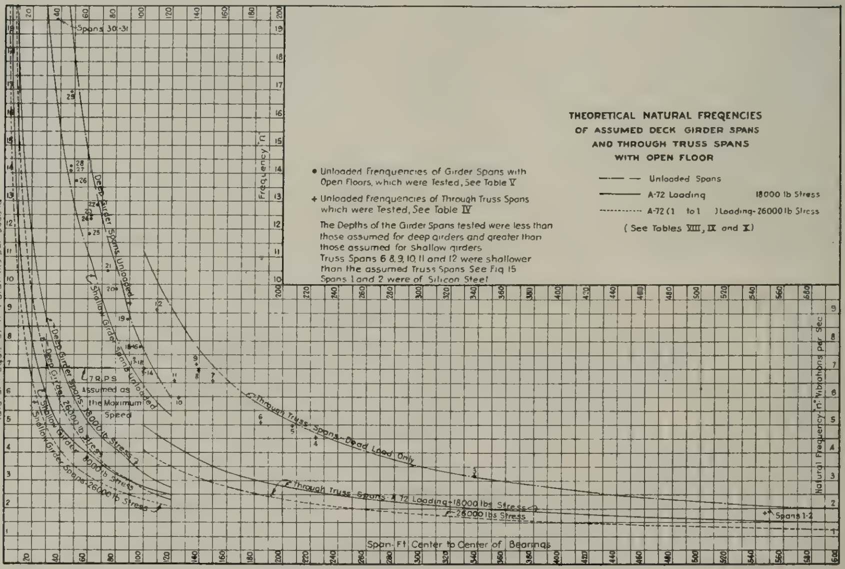


Fig 21

It might at first seem that the increase in magnification under the heavier load would result in larger amount of impact, but for any change in the frequency of the span, n, the force to be magnified, or $Q N^2$, in which $N = n$ when synchronism occurs, varies with the square of the frequency, while the magnification varies directly with n.

On this diagram are plotted the computed dynamic magnifiers of the unloaded truss spans which were tested. It would only be confusing to show the observed magnifiers for the loaded spans, as the stresses produced by the test loads were variable and always much smaller than the assumed stress of 18,000 lb. or 26,000 lb. The amount of magnification may be found, however, by referring to the various diagrams in Appendix B. The magnifiers for the unloaded girder spans, which were tested, have not been shown. They are given in the last column of Table V, and if plotted, they would fall about midway between the values given by the two curves for the unloaded girders.

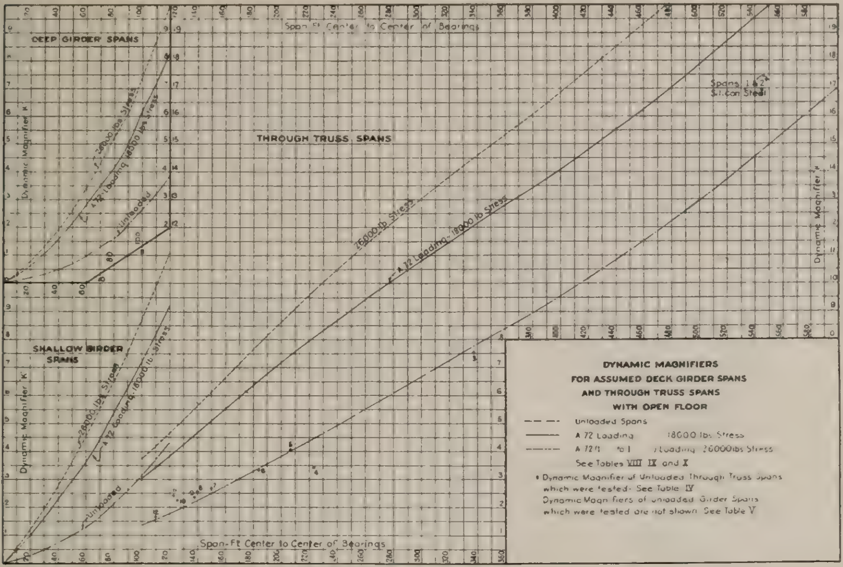


Fig 22

The computed impacts caused by the locomotive and the track irregularities as given in Tables XI, XII and XIII, have been plotted in terms of percentage of live load in Fig. 23. The values being the maximum, as given by either Case I or Case II.

For the girder spans the curves are quite irregular, and unless a table giving the impact percentage for various span lengths is used, it is necessary to establish some curve enclosing the high values. One such curve, as expressed by the equation, Impact per cent $= \frac{450,000}{5000 + L^2} + 12.5$, is shown, L being the length of span in feet. At the time the preliminary report was made to Committee XV, it was suggested that the formula, $116 - 0.77L$, be used for spans up to about 95 ft. in length, and for longer spans, $\frac{1800}{L - 40} + 10$. The Committee felt that the impact allowance for the shorter spans was excessive and proposed the following:

For spans less than 100 ft. in length. . Impact per cent $= 100 - 0.6L$

For spans 100 ft. or more in length. . Impact per cent $= \frac{1800}{L - 40} + 10$

While it may be possible that on spans 20 ft. or less in length, the actual impact might exceed that given by the above formula for short spans, especially if the girders were to act independently and were subject to the wheel rather than one-half the axle hammer blows, the discrepancy is not very serious. On the long spans, it will be seen that the formula gives values greater than those computed for the locomotive hammer blow. This excess is provided to take care of the car impact, which may exceed the locomotive impact on such spans. As might be expected, from what has been said of the effect of the natural frequency on the amount of impact, the impact in the shallow and heavily loaded spans is found to be less than that in the deeper and more lightly loaded spans.

In the lower left-hand corner of the diagram are given the percentages of impact included for the effect of low joints or other track irregularities. They represent the

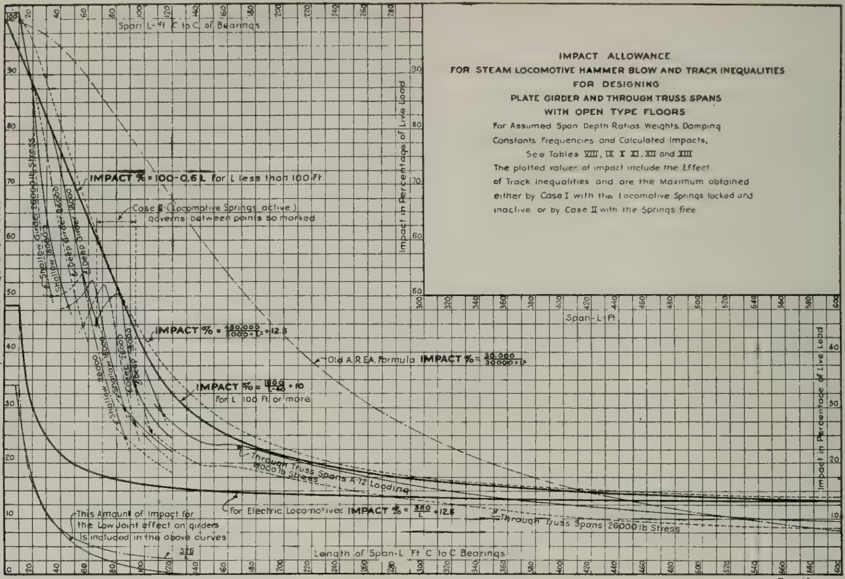


Fig 23

ratio of the moment due to a central track load of 500 N^2 lb., to the live load moment, N being the synchronous speed in r.p.s. This ratio may be expressed quite accurately by the term $\frac{325}{L}$, and, until more definite information is obtained as to the effect of such track irregularities, it is suggested that in rating bridges the amount of impact as given by the above expression be included for the low joint effect.

The curve shown for the amount of impact to be provided for electric locomotives, or other motor equipment having no unbalanced rotating parts, is $\frac{360}{L} + 12.5$. The first term represents the low joint impact, and the second term is an additional allowance for the effect of smoothly rolling loads on the shorter spans and the effect of bouncing cars on the longer spans. This expression might well be $\frac{325}{L} + 12.5$, but in the original report to Committee XV it was suggested that $\frac{360}{L}$ be used as defining the low joint effect, and the electric locomotive impact formula was adopted on that basis.

The amount of impact as determined by the curves or formulas takes care of all of the dynamic effects, except that due to the rolling or lurching of the locomotives and cars. The effect of roll depends upon the spacing of the girders or trusses and must be provided for separately, the amount of this additional impact being $\frac{100}{S}$, in which S is the distance, in feet, between girders, trusses, or columns.

Unless a table, giving the impact allowance for each span length is used, it is difficult to get away from the old method of defining impact in terms length of span and in percentage of live load and, as a matter of convenience, this method has again been resorted to. But the formulas so expressed include the separate effects of all of the known dynamic forces, and take into account the amount of load on the span, the stiffness and natural frequency of the span, the relation between the amount of hammer blow and the static live load, as well as the relative magnitudes of the live load and the dead load. Having assumed and investigated both deep and shallow girders, that is, high and low frequency spans, the impact allowance recommended should be ample for any steel span which is simply supported, providing the assumption as to β, the ratio of hammer blow to live load is a proper one. The weight of the reciprocating parts bears quite a fixed relation to the total weight of the locomotive, and a very heavy locomotive has been selected for this study. With the tendency toward the use of alloy steels giving reciprocating parts of lighter weight and more careful counterbalancing, it would seem that the amount of overbalance which has been assumed is unlikely to be exceeded in future locomotives for which the structures might be designed.

As previously stated, the actual intensity of the assumed loading has but little effect on the amount of impact, as long as the ratio of the amount of hammer blow to total load, or β, remains the same. Spans of similar type, whether of light or heavy design, but having the same length and depth and equally stressed, will have very nearly the same natural loaded frequency, and will consequently be subject to very nearly the same amount of impact. If the dead load on the bridge varied directly with its Moment of Inertia or with the live load, the frequency of a light span, stressed to 18,000 lb. under say an A-36 loading, would be the same as that of another span of equal depth and length which would be subjected to the same stress under an A-72 loading. And if the relative amount of hammer blow, β, were the same for the two loadings, the amount of impact on one span would be the same as that on the other.

There is shown on Fig. 23, the old impact formula of the AREA, which was, Impact $= \frac{30{,}000}{30{,}000 + L^2}$. The excessive amount of impact, given by this formula for span lengths between 60 and 300 ft., can be accounted for by the fact that it was derived from tests made with loads considerably below the span capacity. In other words, the spans under the comparatively light test loads had much higher natural frequencies and consequently would record a greater amount of impact, than would have been found had the loads been such that the stress would more nearly have approached a working stress, say of 18,000 lb. It must also be remembered that the old formula, supposedly at least, included the effect of roll, while to the values derived from the new formula the impact due to rolling must be added, and this may amount to from 12 to 20 per cent for girder spans, and to about 5 per cent for through truss spans.

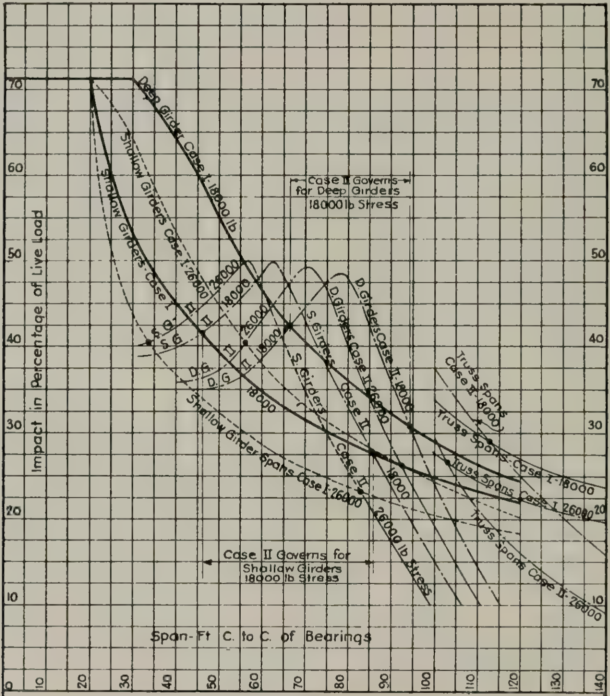
The adopted formulas may be used for rating existing structures as a rough check as to the capacity of the span, but as brought out in the preceding chapter in which subject of rating old bridges was discussed, it would be much better to base such an investigation on the particular locomotive, loading, and span in question.

In Fig. 24 are plotted the calculated impacts due to the locomotive hammer blow for spans up to 140 ft. in length. This diagram is included for the purpose of illustrating the increase in the impact for certain span lengths, due to higher frequencies which occur when spring friction is overcome and oscillation of the sprung weight of the locomotive takes place, this being the condition designated as Case II. It will be seen that, for certain span lengths, the increase for Case II is quite large, particularly for the shallow and more heavily loaded girders. The values for Case II are purely theoretical and may be somewhat excessive, but they should be on the safe side.

(d) Impact at Speeds Other Than Synchronous

The impact allowances, provided by the formulas which have been given, are the maximum to be expected, and are based either on synchronous speeds, or a velocity corresponding to 7 r.p.s. of the locomotive drivers for short spans, on which synchronism cannot occur.

At some point, physical or operating conditions may restrict train speeds to such an extent that it may be desirable to design the structure for a restricted rather than an unlimited speed. If Case II be ignored, the correction in the amount of impact is not very difficult, and it is probable that at any marked reduction from the synchronous speed the forced oscillations would be so small and so slow that the friction of the locomotives would not be overcome.



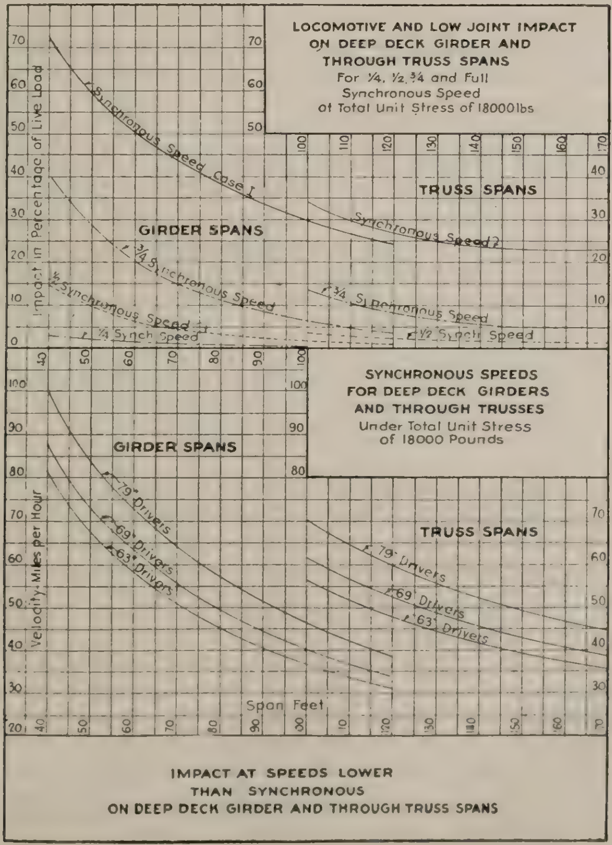
LOCOMOTIVE IMPACT
ON DECK GIRDER AND THROUGH TRUSS SPANS
For Case I - with the Locomotive Springs Locked
and Case II with the Locomotive Springs Free.

Fig. 24

On short spans whose frequency is so high that synchronism cannot be attained, the magnification of the alternating force is unity, and, as has been shown, the locomotive impact is simply βN^2, in which N has been assigned a value of 7, as a maximum. At fractional speeds of ¼, ½, and ¾, the corresponding impacts become 1/16, ¼ and 9/16, of that at the maximum speed, or $\frac{49\beta}{16}$, $\frac{49\beta}{4}$ and $\frac{441\beta}{16}$. There would also be a corresponding reduction in the low joint impact, as the equivalent force, for this effect, has been assumed as a central track load of 500 N^2 lb. There would be no reduction in the allowance for rolling.

For longer spans, whose frequency, *n*, is within the range of possible speed, synchronism, with magnification of the alternating force, takes place, and the locomotive impact, *I*, as long as the springs remain locked, is $\frac{D_h n^2 k}{D}$, or $\beta n^2 k$, the dynamic magnifier, *k*, at synchronous speed ($N = n$) being $\frac{1}{\Delta} = \frac{1}{2pn}$. At any fractional speed, as expressed by $\frac{N}{n} = S$, the dynamic magnifier, k_1, at that speed, is, $\frac{1}{\sqrt{(1-S^2)^2 + (\Delta S)^2}}$, the impact, I_1, is $\beta N^3 k_1$, and $\frac{I_1}{I} = \frac{\beta N^3 k_1}{\beta n^2 k} = S^2 \frac{k_1}{k}$. As $\frac{N}{n}$, or *S*, becomes small, the amount of magnification, k_1, decreases quite rapidly, and this decrease in magnification is accompanied by greater decrease in the value of *S*, so that the amount of locomotive impact becomes very small, as *N* decreases with respect to *n*. The low joint impact is also proportional to S^2, so that on such spans it becomes negligible at low speeds.

The locomotive and joint impact, which might be expected at fractional speeds of ¼, ½, and ¾ of the synchronous speed, has been computed for deep deck girder spans from 40 to 120 ft. in length, and through truss spans from 100 to 170 ft. in length, for the A-72 loading, or 18,000 lb. stress. The results are shown in the upper diagram of Fig. 25. Even at ¾ speed, there is a large reduction in the amount of impact. In the


LOCOMOTIVE AND LOW JOINT IMPACT ON DEEP DECK GIRDER AND THROUGH TRUSS SPANS
For ¼, ½, ¾ and Full Synchronous Speed of Total Unit Stress of 18000 lbs

SYNCHRONOUS SPEEDS FOR DEEP DECK GIRDERS AND THROUGH TRUSSES
Under Total Unit Stress of 18000 Pounds

IMPACT AT SPEEDS LOWER THAN SYNCHRONOUS ON DEEP DECK GIRDER AND THROUGH TRUSS SPANS

Fig 25

lower diagram are given the velocities, in m.p.h., corresponding to the synchronous speeds in r.p.s., for various sizes of driving wheels, the synchronous speed being determined from the natural frequencies, *n*, of the loaded spans, which are given in Tables VIII and X, or XI and XIII.

It should be remembered that the reduced speed must be expressed in terms of the synchronous speed and not as a fraction of the maximum possible speed. With a fractional speed of ¾, the locomotive impact becomes less than 15 per cent on spans of more than 70 ft. in length, and this perhaps should be taken as the minimum, in order to provide for the effect of bouncing cars. The usual allowance for rolling and lurching should be added.

(e) IMPACT ON SPANS, OTHER THAN DECK GIRDERS AND DEEP SINGLE TRACK THROUGH TRUSSES, WITH OPEN FLOORS, AND OF CARBON STEEL

(1) **Through Girder Bridges.** In through girders, having the same intensity of stress, the impact should be the same or somewhat less than that in deck girders of the same span and depth. However, if the span has a floor system consisting of longitudinal stringers, which takes a portion of the lower flange stress, it will be stiffer than the deck span, and be subjected to a larger amount of impact, but the static flange stress will be smaller. The allowance for roll will be less, due to the wider spacing of the girders.

(2) **Deck and Half Through Trusses and Spans of Alloy Steel.** Deck and half-through spans, being shallow, would have lower frequencies than the assumed truss spans, and would be subjected to a smaller amount of impact than given by the proposed formula. The same may be said of spans fabricated of the alloy steels. With the higher working stresses, they would be less stiff than spans of ordinary structural steel, and consequently would have lower frequencies, which would result in less impact.

(3) **Spans with Solid Floors and Ballasted Track.** There are so many different types of ballasted deck spans that it would be difficult to select some typical design, as was done with open deck bridges, and estimate the amount of impact to be expected, even if sufficient information as to the damping in such bridges were at hand. The spans which were tested were found to be very stiff and of high frequency, due to the floor acting as an integral part of the girders. A large amount of damping was present, but just how much of this can be ascribed to the cushioning effect of the ballast is unknown. Bridges with plank or precast concrete slab floors were not tested, but they should have lower frequencies with less damping. It can be seen from the expression, Impact $= \frac{\beta n}{2p}$, that if the ratio of frequency to damping is less in bridges with solid floors than in those with open floors, the impact will be less. It can scarcely be more, but until further tests are made, it is suggested that the formulas given for the design of open deck bridges be used for designing bridges carrying ballasted track.

(4) **Multiple Track Spans.** In computing the impact for the single track spans used in this analysis, the full effect of the hammer blow from both of the double headed locomotives on the longer spans was taken into account. This method is conservative, at least, as it implies that the counterweights on both engines are in the same angular position, or phase, which would rarely be the case. If they were directly opposite, that is 180° apart, the effect of one would counteract that of the other.

For spans carrying two tracks, but of such length that the maximum static effect results from the single engine and train, an allowance for full impact from both tracks might be provided, based on the same assumption that the hammer blows from two locomotives might be in phase. This would apply to spans of less than 175 ft. in length. On double track spans, more than 175 ft. long, four locomotives produce the maximum static effect, but it is inconceivable that they should all be running at exactly the same speed, in r.p.s, or that their hammer blows should all be in phase, so that it seems unnecessary to consider the impact from more than one track, when designing such structures. It will be necessary, however, to establish some range of span length, say from 175 to 225 ft., in which the impact from the second track changes from the full amount to nothing. The amount to be included from the second track may be expressed in percentage of the full impact, as $450 - 2L$.

With spans of any length carrying more than two tracks a provision for the full impact from any two tracks should be sufficient.

(f) SUMMARY

The methods by which the proposed impact formulas were derived have been fully outlined. They are based principally on the assumption that the stationary locomotive with skidding drivers can be substituted for the engine moving across the span. Such an assumption simplifies the solution of this problem, and the close agreement between the theoretical and measured values of the oscillations and dynamic magnifiers, as will be found in most of the diagrams in Appendix B, would indicate that it is not greatly in error. Theory, which is so well verified by tests on a group of existing spans, may be used with confidence in estimating the amount of impact to be expected in other similar spans.

The impact allowances, as recommended by the Committee on Iron and Steel Structures, were based upon the tests and theory as herein described. Its recommendation, as contained in Articles 206 and 207, of the revised Specifications for Steel Railway Bridges, was adopted by the Association in March, 1935, and is:

Impact.

206. "To the maximum computed live load stresses there shall be added the impact, consisting of:

(a) The lurching effect:

A percentage of the static live load stress equal to $\frac{100}{S}$

S = spacing, in feet, between centers of longitudinal girders, stringers, or trusses; or length, in feet, of floor beams or transverse girders.

(b) The direct vertical effect:

With steam locomotives (hammer blow, track irregularities, and car impact), a percentage of the static live load stress equal to:

For L less than 100 feet .... $100 - 0.6L$

For L 100 feet or more .... $\frac{1800}{L - 40} + 10$

With electric locomotives (track irregularities and car impact), a percentage of the static live load stress equal to .. $\frac{360}{L} + 12.5$

L = length, in feet, center to center of supports for stringers, longitudinal girders, and trusses (chords and main web members).

or L = length of floor beams or transverse girders, in feet, for floor beams, floor beam hangers, subdiagonals of trusses, transverse girders, and supports for transverse girders.

The impact shall not exceed 100 per cent of the static live load."

207. "For members receiving load from more than one track, the impact percentage shall be applied to the static live load on the number of tracks shown below:

Load received from:

Two tracks:

For L less than 175 feet	Full impact on two tracks.
For L from 175 to 225 feet	Full impact on one track and a percentage of full impact on the other as given by the formula, $450 - 2L$.
For L greater than 225 feet	Full impact on one track and none on the other.

More than two tracks:

For all values of L	Full impact on any two tracks."

(IX) CONCLUSIONS

Any formula or method used for the purpose of estimating the amount of impact in railway bridges should provide for the combined effect of each of the dynamic forces acting on the particular span in question. These forces may result from the hammer blow of the steam locomotive, track irregularities and oscillation of the sprung weight of cars, the largest part of the impact on most spans being due to the locomotive. The theory of vibrations, insofar as it applies to the effect of the steam locomotive on bridges of simple span, has recently been developed to such an extent that we now have a means of dealing with this most important feature of the impact problem. Fortunately, theory seems well enough substantiated by tests to justify the following conclusions:

1. The amount of impact from the steam locomotive depends upon:

(a) *The natural frequency of the span.* Its frequency is determined by its stiffness and the load which it carries. For the same intensity of loading deep spans will have higher frequencies than shallow spans, and for the same degree of stiffness, lightly loaded spans will have higher frequencies than heavily loaded spans.

(b) *The intensity of the forces, internal and external, opposing bridge vibration, or the amount of damping.* The internal force, due to the elastic friction in the material itself, depends upon the frequency of the span, that is, upon its stiffness and the amount of load it carries. Damping of this nature is less in spans of low frequency than in those of high frequency.

The external force is largely due to end bearing friction, and depends upon the type and condition of the bearings. On some spans additional damping may result from friction in the springs of locomotives and cars, after the springs are once set in motion.

(c) *The amount of excess counterweight on the drivers of the locomotive.* For any one span and for the same intensity of loading, the locomotive impact at any speed is directly proportional to the amount of the overbalance.

(d) *The relation between the speed of the locomotive, in r.p.s., and the natural frequency of the loaded span.*

2. When definite values can be assigned to the above factors, the amount of impact resulting from the operation of any locomotive on any span can be closely estimated. Any impact formula which ignores these factors will give unreliable results.

3. The recently discarded impact formula of the American Railway Engineering Association gave impact values which were too high for many spans, particularly those between 50 and 250 ft. in length. This discrepancy was largely due to the fact that the formula was derived from tests made on spans with high frequencies under the comparatively light test loads, without any correction to compensate for the reduction in impact resulting from the lower frequency of the span when loaded to capacity.

4. The formula which has just been adopted should provide a safe impact allowance for designing any steel span which is simply supported. It should also be safe for rating old structures, but in determining the capacity of existing bridges it would be much better to investigate the particular span for the contemplated loading, as explained in Part VII.

5. While the information, obtained from the British experiments and from the tests herein reported, is sufficient to justify the revision of the impact formula, further investigation would be valuable. With additional data it is probable that the formula might be improved, or be revised insofar as it applies to certain types of bridges, such as spans with ballasted track. Additional data is needed as to:

(a) *Damping.* Any further tests, in which the oscillations are measured, will provide additional information as to span damping factors or constants, but it would be interesting to know more about the origin of these forces which oppose vibration, that is, the relative effect of internal and external friction.

(b) *Effect of low joints or track irregularities.* For the lack of any definite information, it has been necessary to make an approximation as to the effect of low joints. On very short spans, the allowance for this effect constitutes a large part of the total impact, and some determination of the actual low joint impact should be made. These tests could best be made with electric locomotives, thus eliminating the factor of hammer blow, and with stress recorders of the electric type. Runs with both continuous and jointed rails should be made on open and ballasted deck bridges. It may be that the use of long rails or welded joints on short spans would be most economical, especially if the capacity of the structure were limited.

(c) *Bridges with solid floors.* Additional tests on bridges having solid floors with ballasted track are needed, especially on spans with timber or precast floors. Some investigation should be made as to the distribution of load between the stringers or girders, where more than two are used, and where there is any eccentricity of loading.

(d) *Car Impact.* Additional information is needed as to the effect of the oscillation of the sprung weight of freight cars, particularly on long spans.

(e) *Locomotive Spring Friction.* Theory, and tests to a lesser extent, indicate that the friction in the locomotive springs contributes, on some spans at least, additional damping. It is also possible that, when the springs are acting, the impact, at certain speeds, may be greater than would have been the case had the springs remained locked. Little is known as to the actual spring friction and spring frequencies or as to action of the sprung mass. This phase of the problem is complicated, but it may be the governing factor in fixing the amount of impact on spans from about 40 to 90 ft. in length, and more information as to the action and effect of the oscillating sprung weight of equipment should be obtained.

(f) *Counterbalancing of Locomotives.* Some joint investigation should be made as to locomotive counterbalancing. Some consideration has been given to the reduction in the hammer blow of the individual drivers, and this has been of benefit as to the effect on track, but on bridges it is necessary to provide for the dynamic augment of the entire locomotive. It is probable that when the counterbalance reports are examined, the same wide variation in the amount of excess counterbalance, as given in Table XIV, will be found for the locomotives of most railroads. It is difficult for the Bridge Engineer to understand why, if it is satisfactory to counterbalance 25 or 30 per cent of the weight of the reciprocating parts on one class of locomotives, it is necessary to counterbalance 50 to 60 per cent on some similar class. In addition to establishing the lowest satisfactory limit for this proportion, it would seem that some thought should be given to the reduction in weight of the reciprocating parts.

It is interesting to note, in this connection, that by the use of alloy steel, the weight of the reciprocating parts of the new high speed locomotives, recently built for the C.M.St.P. & P.R.R., has been held to 1003 lb. The total weight of the locomotive is 280,000 lb., or the weight of the reciprocating parts is only 1/280 of the weight of the locomotive as against the usual proportion of 1/150 to 1/200. And only one-third of this weight is counterbalanced. If all locomotives could be so designed the impact allowance could be materially reduced.

ACKNOWLEDGMENT

The valuable work done by Professors C. E. Inglis, S. Timoshenko, F. E. Turneaure, and others, in connection with the theory of vibrations in railroad bridges, has been acknowledged. Without some such means of interpreting the results, the tests which have been described would have been of but little value.

The tests were conducted under unfavorable conditions, and the accomplishment of this work is due, in a large part, to the unstinted efforts of those who, at various times, were engaged in the work. The field records were taken by Messrs. G. E. Robinson, G. E. Scheffer, A. H. Schmidt and A. A. Keever, and these men spent long hours, in all kinds of weather, in order to record every possible train. The tedious compilation of the test data and the many computations were the work of Mr. A. M. Westenhoff and Mr. G. P. Davis.

The instruments were constructed, largely from odds and ends, under the capable supervision of Mr. G. E. Nicholson and Mr. A. J. Kelly.

For the information as to the locomotives, of their respective Railroads, used in the tests on certain bridges, the author is indebted to Mr. Porter Allen of the Pennsylvania and Mr. F. H. Howard of the Erie. Others contributed many helpful suggestions, and their interest in the work was a source of encouragement and was highly appreciated.

Appendix A

LOCOMOTIVES USED IN TESTS

There were about 300 different locomotives, representing 43 different classes, used in the tests. With the exception of a few engines of the Pennsylvania Railroad, used in testing Spans 32, 33, 34, 35 and 38, and the Erie engines used on Span 8, they were all owned by the Cleveland, Cincinnati, Chicago and St. Louis Railway Company.

The information as to their weight, wheel spacing, counterbalancing, etc. is given in Table XIV. But one or two items should need any explanation. The values given for the locomotive spring frequency are the computed frequencies based on the loaded deflection of the springs over the drivers, the other springs usually having slightly different deflections.

While there is a large variation in the weight of the reciprocating parts, it will be seen that the weight of the locomotive bears a rather fixed relation to the weight of these parts. This proportion ranges from 159 to 215, but for most of the engines it is about 180.

B

95,5

09,6
05,1

78,0

09,6
37,6

03,0

4,80
7,80

01,00

4,80
5,80

7.50
4.80
2,30
2,00
4.80
6,80

2,00

0.30
2,30

3,00

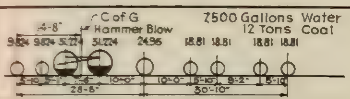
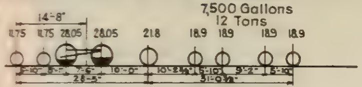
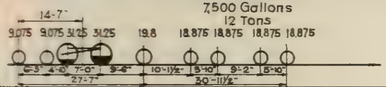
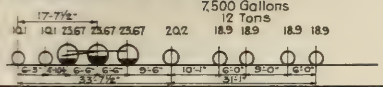
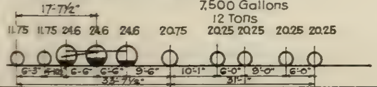
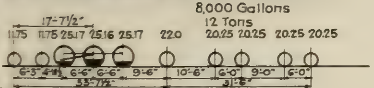
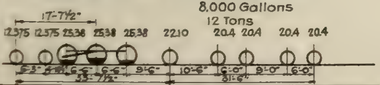
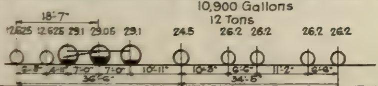
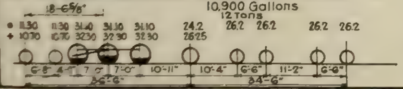
3,00
6.00

1,50

2,40
3,90

BIG FOUR PASSENGER LOCOMOTIVES

TABLE XIV ①

Class of Locomotive	Wheel Loads, Wheel Spacing and Location of Resultant of Counter Weight Hammer Blows.		Date	Weight of Engine (Kips)		Freq. of Loc. Springs	Drivers			Speed at 1 R.P.S.		Wght. of Recipro. Parts	Wght Eng. / Recip Parts	Recip Weights Ballanced						Hammer Blow at 1 R.P.S.						Total H.B. / Wght. Eng.	Locomotives used in Tests		Class of Locomotive
				Live	Dead		Crank Pin Rad.	Diam. (ins)	Circum. (Ft)	F.P.S.	M.P.H.			Driver				Total	%	Driver (One Side)				Total			Engine No	On Span No	
														1	2	3	4			1	2	3	4	One Side	Eng				
I-61	 14'-8" C of G Hammer Blow 7500 Gallons Water 12 Tons Coal 9.824 9.824 31.224 31.224 24.96 18.81 18.81 18.81 18.81 5'-10" 5'-11" 7'-6" 10'-0" 10'-0" 5'-10" 9'-2" 5'-10" 28'-5" 30'-10"	Weight of Engine 200,900 Weight of Tender Loaded 151,000 Total Weight 351,900	'02	156.44 (77.9%)	44.46 (22.1%)	1.98	13"	79	20.7	20.7	14.1	1137	177	284	284			568	50	378	378			756	1068	.00531	6912	13	I-61
I-62	 7,500 Gallons 12 Tons 14'-8" 11.75 11.75 28.05 28.05 21.8 18.9 18.9 18.9 18.9 5'-10" 5'-7" 7'-6" 10'-0" 10'-2¾" 5'-10" 9'-2" 5'-10" 28'-5" 31'-0½"	Weight of Engine 202,800 Weight of Tender Loaded 151,200 Total Weight 354,000	'03	158.34 (78.1%)	44.46 (21.9%)	1.98	13"	79	20.7	20.7	14.1	1137	178	284	284			568	50	378	378			756	1068	.00526	6915, 16	13 14	I-62
I-J	 7,500 Gallons 12 Tons 14'-7" 9.075 9.075 31.25 31.25 19.8 18.875 18.875 18.875 18.875 6'-3" 4'-10" 7'-0" 9'-6" 10'-1½" 5'-10" 9'-2" 5'-10" 27'-7" 30'-11½"	Weight of Engine 214,100 Weight of Tender Loaded 151,000 Total Weight 365,100	'06	155.06 (77.5%)	44.94 (22.5%)	1.98	13"	79	20.7	20.7	14.1	1137	189	284	284			568	50	378	378			756	1068	.00498	6954	13 14	I-J
○ K + K-B	 7,500 Gallons 12 Tons 17'-7½" 10.1 10.1 23.67 23.67 23.67 20.2 18.9 18.9 18.9 18.9 6'-3" 4'-10½" 6'-6" 6'-6" 9'-6" 10'-1" 6'-0" 9'-0" 6'-0" 33'-7½" 31'-1"	Weight of Engine 222,800 Weight of Tender Loaded 151,200 Total Weight 374,000	'05 '06	164.16 (73.7%) 164.16 (73.7%)	58.64 (26.3%) 58.64 (26.3%)	1.98 1.98	13" 13"	75 75	19.64 19.64	19.6 19.6	13.4 13.4	1339 1339	167 167	223 223	223 223	223 223		669 669	50 50	295 295	295 295	295 295		885 885	1251 1251	.00561 .00561	○ 6401 + 6412, 16	+ 7 ○+}20 + 25 + 26 ○ 27 ○ 28	○ K + K-B
K-H	 7,500 Gallons 12 Tons 17'-7½" 11.75 11.75 24.6 24.6 24.6 20.75 20.25 20.25 20.25 20.25 6'-3" 4'-10½" 6'-6" 6'-6" 9'-6" 10'-1" 6'-0" 9'-0" 6'-0" 33'-7½" 31'-1"	Weight of Engine 236,000 Weight of Tender Loaded 162,000 Total Weight 398,000	'10	177.36 (75.2%)	58.64 (24.8%)	1.98	13"	75	19.64	19.6	13.4	1339	176	223	223	223		669	50	297	297	297		891	1260	.00534	6425, 29	4 6 23 25 26	K-H
K-K	 8,000 Gallons 12 Tons 17'-7½" 11.75 11.75 25.17 25.16 25.17 22.0 20.25 20.25 20.25 20.25 6'-3" 4'-10½" 6'-6" 6'-6" 9'-6" 10'-6" 6'-0" 9'-0" 6'-0" 33'-7½" 31'-6"	Weight of Engine 242,000 Weight of Tender Loaded 162,000 Total Weight 404,000	'12	183.36 (75.8%)	58.64 (24.2%)	1.98	13"	75	19.64	19.6	13.4	1278	189	222	213	213		648	50.8	293	281	281		855	1209	.00496	6435, 37, 42, 44,	4 6 22 23 24	K-K
○ K-N + K-O	 8,000 Gallons 12 Tons 17'-7½" 12.375 12.375 25.38 25.38 25.38 22.10 20.4 20.4 20.4 20.4 6'-3" 4'-10½" 6'-6" 6'-6" 9'-6" 10'-6" 6'-0" 9'-0" 6'-0" 33'-7½" 31'-6"	Weight of Engine 246,000 Weight of Tender Loaded 163,200 Total Weight 409,200	'15 '15	187.36 (76.2%) 187.36 (76.2%)	58.64 (23.8%) 58.64 (23.8%)	1.98 1.98	13" 13"	75 75	19.64 19.64	19.6 19.6	13.4 13.4	1278 1278	192 192	213 213	213 213	213 213		639 639	50 50	283 283	283 283	283 283		849 849	1200 1200	.00489 .00489	○ 6446, 49 + 6451	○ 7 + 9 +○ 20 ○ 21 + 27	○ K-N + K-O
○ K3-J + K3-K × K3-L	 10,900 Gallons 12 Tons 18'-7" 12.625 12.625 29.1 29.05 29.1 24.5 26.2 26.2 26.2 26.2 3'-8" 4'-11" 7'-0" 7'-0" 10'-11" 10'-8" 6'-6" 11'-2" 6'-6" 36'-6" 34'-6"	Weight of Engine 274,000 Weight of Tender Loaded 209,600 Total Weight 483,600	'17	210.98 (77.0%)	63.02 (23.0%)	1.98	13"	79	20.7	20.7	14.1	1723	159	287	287	287		861	50	379	379	379		1137	1603	.00585	○ 6455, 56, 57, 58, 59 + 6460, 61, 63, 64, 65, 66, 67, 68 × 6470, 72, 73, 74	+×}4 +×}6 +×}7 × 9 × 11 ○×}13 ○×}15 ○×}16 ○ 19 +×}20 + 21 + 23 ○+}25 ○+×}26 ○×}27 + 28 ○ 29 +×}34 +×}35 × 38 × 39	○ K3-J + K3-K × K3-L
K3-P ○ Type-I + Type-II (BOOSTER)	 10,900 Gallons 12 Tons 18'-6⅝" ○ 11.30 11.30 31.10 31.10 31.10 24.2 26.2 26.2 26.2 26.2 + 10.70 10.70 32.30 32.30 32.30 26.25 6'-8" 4'-1" 7'-0" 7'-0" 10'-11" 10'-4" 6'-6" 11'-2" 6'-6" 36'-6" 34'-6"	○ Weight of Engine 280,200 Weight of Tender Loaded 209,600 Total Weight 489,800 + Weight of Engine 289,100 Weight of Tender Loaded 209,600 Total Weight 498,700	'20 '20	217.71 (77.8%) 225.99 (78.2%)	62.29 (22.2%) 63.11 (21.8%)	1.98 1.98	13" 13"	79 79	20.7 20.7	20.7 20.7	14.1 14.1	1718 1718	163 168	376 376	366 366	371 371		1113 1113	64.8 64.8	496 496	483 483	490 490		1469 1469	2076 2076	.00741 .00718	○ 6476, 77, 78, 79, 80 + 6483	○ 8 ○ 15 ○ 16 ○ 21 ○ 34 ○ 35 ○ 38 ○ 39 + 20	K3-P ○ Type I + Type II (BOOSTER)

E

4,00

1,20
5,20

6,00

1,20
7,20

7,80

5,60
3,40

7,80

3,50
1,30

5,70

0,50
6,20

,700

,000
,700

,300

,500
,800

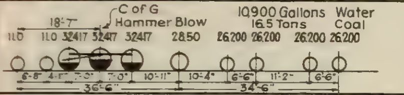
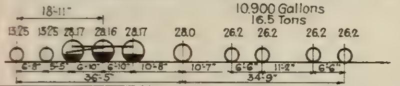
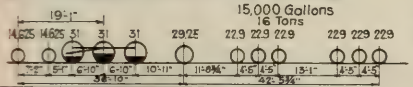
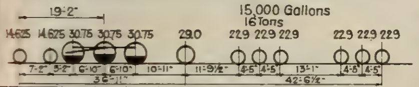
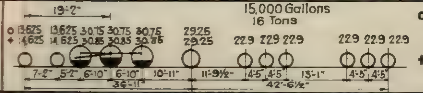
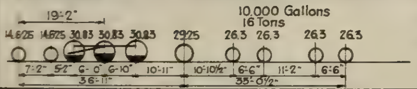
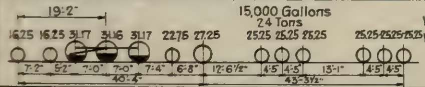
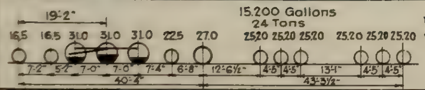
,300
,000
,300
,200
,000
,200

,500

,300
,800

BIG FOUR PASSENGER LOCOMOTIVES

TABLE XIV ②

Class of Locomotive	Wheel Loads, Wheel Spacing and Location of Resultant of Counter Weight Hammer Blows.	Date	Wghts of Engine (Kips)		Freq. of Loc. Springs	Drivers			Speed at I.R.P.S		Wght. of Recipro. Parts	Wght. Eng. / Rec. Parts	Recip. Weights Balanced						Hammer Blow at I.R.P.S.						Total H.B. / Wght. Eng.	Locomotives used in Tests		Class of Locomotive
													Driver				Total	%	Driver (one side)				Total					
			Live	Dead		Crank Pin Rad.	Diam. (ins)	Circum. (Ft.)	F.P.S.	M.P.H.			1	2	3	4			1	2	3	4	One Side	Enq.		Engine No.	On Span No.	
K3-Q	 18'-7" C of G Hammer Blow 10,900 Gallons Water 16.5 Tons Coal 11.0 11.0 32417 32417 32417 28.50 26.200 26.200 26.200 26.200 6'-8" 4'-11" 7'-0" 7'-0" 10'-11" 10'-4" 6'-6" 11'-2" 6'-6" 36'-6" 34'-6" Weight of Engine 295,500 Weight of Tender Loaded 209,600 Total Weight 505,100	'23	232.39 (78.6%)	63.11 (21.4%)	1.98	13"	79	20.7	20.7	14.1	1771	167	295	295	295		885	50	389	389	389		1167	1650	.00556	6485, 86, 87, 88, 90, 91, 93, 6495, 97, 98	4 6 7 9 13 15 16 19 20 21 23 25 26 27 29 30 31 34 35 39	**K3-Q**
K3-R	 18'-11" 10,900 Gallons 16.5 Tons 13.25 13.25 28.17 28.16 28.17 28.0 26.2 26.2 26.2 26.2 6'-8" 5'-5" 6'-10" 6'-10" 10'-8" 10'-7" 6'-6" 11'-2" 6'-6" 36'-5" 34'-9" Weight of Engine 278,000 Weight of Tender Loaded 209,600 Total Weight 487,600	'25	215.83 (77.6%)	62.17 (22.4%)	1.98	13"	79	20.7	20.7	14.1	1565	178	261	261	261		783	50	345	345	345		1035	1463	.00527	6500, 02	4 6 13 22	**K3-R**
K-5	 19'-1" 15,000 Gallons 16 Tons 14.625 14.625 31 31 31 29.25 22.9 22.9 22.9 22.9 22.9 22.9 7'-2" 5'-1" 6'-10" 6'-10" 10'-11" 11'-8¾" 4'-5" 4'-5" 13'-1" 4'-5" 4'-5" 38'-10" 42'-5¾" Weight of Engine 303,000 Weight of Tender Loaded 274,800 Total Weight 577,800	'24			1.98	14"	79	20.7	20.7	14.1	1648	184	275	275	275		825	50	394	394	394		1182	1671	.00518	6525	7 13 20 25 30	**K-5**
K5-A	 19'-2" 15,000 Gallons 16 Tons 14.625 14.625 30.75 30.75 30.75 29.0 22.9 22.9 22.9 22.9 22.9 22.9 7'-2" 5'-2" 6'-10" 6'-10" 10'-11" 11'-9½" 4'-5" 4'-5" 13'-1" 4'-5" 4'-5" 36'-11" 42'-6½" Weight of Engine 301,000 Weight of Tender Loaded 274,800 Total Weight 575,800	'25	243.1 (80.8%)	57.9 (19.2%)	1.98	14"	79	20.7	20.7	14.1	1539	195	256	256	256		768	50	367	367	367		1101	1558	.00517	6256, 27, 29	9 14 22 24 36	**K5-A**
K5-B ∘Type I +Type II (F.W. HEATER)	 19'-2" 15,000 Gallons 16 Tons ∘ 13.625 13.625 30.75 30.75 30.75 29.25 + 14.625 14.625 30.85 30.85 30.85 29.25 22.9 22.9 22.9 22.9 22.9 22.9 7'-2" 5'-2" 6'-10" 6'-10" 10'-11" 11'-9½" 4'-5" 4'-5" 13'-1" 4'-5" 4'-5" 36'-11" 42'-6½" ∘ Weight of Engine 297,500 Weight of Tender Loaded 274,800 Total Weight 572,300 + Weight of Engine 302,000 Weight of Tender Loaded 274,800 Total Weight 576,800	'26 '27	239.6 (80.5%) 244.1 (80.9%)	57.90 (19.5%) 57.90 (19.1%)	1.98 1.98	14" 14"	79 79	20.7 20.7	20.7 20.7	14.1 14.1	1542 1542	193 196	257 257	257 257	257 257		771 771	50 50	368 368	368 368	368 368		1104 1104	1560 1560	.00521 .00516	∘6505, 06, 07, 08, 09, 10, 11, 12 ∘6513, 14 +6515, 16, 17, 18, 19, 20, 21, 24	∘+}4 ∘+}6 ∘7 ∘8 ∘+}9 ∘+}13 ∘+}14 ∘+}15 ∘16 ∘+}20 ∘+}21 ∘+}22 ∘23 ∘+}24 ∘+}25 ∘26 ∘27 ∘28 ∘30 ∘31	**K5-B** Type I Type II (F.W. HEATER)
K5-B Type III (SHORT TENDER)	 19'-2" 10,000 Gallons 16 Tons 14.625 14.625 30.83 30.83 30.83 29.25 26.3 26.3 26.3 26.3 7'-2" 5'-2" 6'-0" 6'-10" 10'-11" 10'-10½" 6'-6" 11'-2" 6'-6" 36'-11" 35'-0½" Weight of Engine 302,000 Weight of Tender Loaded 210,300 Total Weight 512,300	'27	244.1 (80.9%)	57.9 (19.1%)	1.98	14"	79	20.7	20.7	14.1	1542	196	257	257	257		771	50	368	368	368		1104	1560	.00516	6531, 32, 33, 34, 35, 36, 37, 38 6539, 40	15 16 19 20 21 29 34	**K5-B** Type III (SHORT TENDER)
J1-D	 19'-2" 15,000 Gallons 24 Tons 16.25 16.25 31.17 31.16 31.17 22.75 27.25 25.25 25.25 25.25 25.25 25.25 25.25 7'-2" 5'-2" 7'-0" 7'-0" 7'-4" 6'-8" 12'-6½" 4'-5" 4'-5" 13'-1" 4'-5" 4'-5" 40'-4" 43'-3½" Weight of Engine 353,000 Weight of Tender Loaded 303,000 Total Weight 656,000	'29	285.30 (80.8%)	67.70 (19.2%)	1.90	14"	79	20.7	20.7	14.1	1971	179	262	306	276		844	42.8	372	435	392		1199	1691	.00479	6600, 01, 02, 03, 04, 05, 06, 07, 08, 6603, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 8224, 25	4 6 7 9 13 14 15 16 19 20 21 22 24 25 27 29 34 35 36 37 38 39	**J1-D**
J1-E	 19'-2" 15,200 Gallons 24 Tons 16.5 16.5 31.0 31.0 31.0 22.5 27.0 25.20 25.20 25.20 25.20 25.20 25.20 7'-2" 5'-2" 7'-0" 7'-0" 7'-4" 6'-8" 12'-6½" 4'-5" 4'-5" 13'-1" 4'-5" 4'-5" 40'-4" 43'-3½" Weight of Engine 351,500 Weight of Tender Loaded 302,400 Total Weight 653,900	'31			1.90	14"	79	20.7	20.7	14.1	1961	178	301	*235 (452)	299		835	42.6	427	334	425		1186	1672	.00475	6620, 21, 22, 23, 24, 25, 26, 27, 28 6629	4 6 13 14 15 20 22 23 24 34 35 36 37 38 39	**J1-E**

* Cross Counter Balanced

B

90,800
35,600
76,400

28,000
3,600
1,600

54,900
3,600
8,500
55,900
3,600
9,500

43,100
76,000
19,100

35,000
76,000
11,000

54,500
76,000
0,500

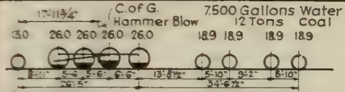
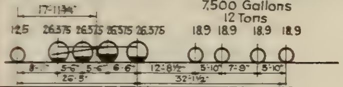
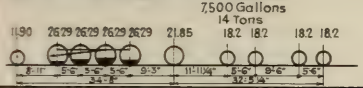
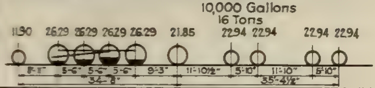
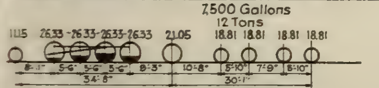
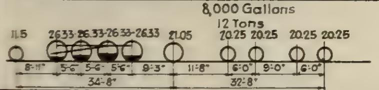
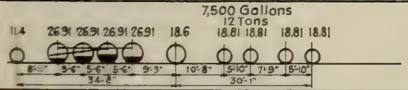
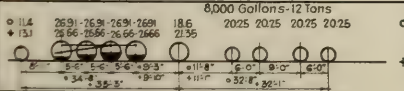
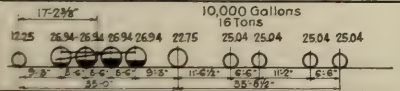
54,000
92,300
56,300

67,000
09,600
76,600

55,000
10,000
75,000

BIG FOUR FREIGHT LOCOMOTIVES

TABLE XIV ③

Class of Locomotive	Wheel Loads, Wheel Spacing and Location of Resultant of Counter Weight Hammer Blows.	Date	Weights of Engine (Kips)		Freq. of Loc Springs	Drivers			Speed at 1 R.P.S.		Weight of Recipro. Parts	Wght. Eng. / Rec Parts	Recip Weights Balanced						Hammer Blow at 1 R.P.S.						Total H.B. / Wght. Eng.	Locomotives used in Tests		Class of Locomotive
			Live	Dead		Crank Pin Rad	Diam. (ins)	Circum. (Ft)	F.P.S.	M.P.H.			Driver				Total	%	Driver (One Side)				Total			Engine No.	On Span No.	
													1	2	3	4			1	2	3	4	One Side	Eng.				
G6-C	 17'-11¾" C. of G. Hammer Blow 7500 Gallons Water 12 Tons Coal 13.0 26.0 26.0 26.0 26.0 18.9 18.9 18.9 18.9 8'-11" 5'-6" 5'-6" 6'-6" 13'-8½" 5'-10" 9'-2" 5'-10" 26'-5" 34'-6½" Weight of Engine 234,000 Weight of Tender Loaded 151,200 Total Weight 385,200	'07	179.13 (76.6%)	54.87 (23.4%)	2.29	16"	63	16.49	16.5	11.3	1410	166	176	165	176	199	716	50.8	288	270	288	326	1172	1660	.00709	6734	15 16	**G6-C**
G6-N	 17'-11¾" 7,500 Gallons 12 Tons 12.5 26.375 26.375 26.375 26.375 18.9 18.9 18.9 18.9 8'-11" 5'-6" 5'-6" 6'-6" 12'-8½" 5'-10" 7'-9" 5'-10" 26'-5" 32'-1½" Weight of Engine 236,000 Weight of Tender Loaded 151,200 Total Weight 387,200	'10	181.13 (76.7%)	54.87 (23.3%)	2.29	16"	63	16.49	16.5	11.3	1410	167	176	165	176	199	716	50.8	288	270	288	326	1172	1660	.00703	6789	15	**G6N**
H5-LA TYPE I (7500 GAL. TANK)	 7,500 Gallons 14 Tons 11.90 26.29 26.29 26.29 26.29 21.85 18.2 18.2 18.2 18.2 8'-11" 5'-6" 5'-6" 5'-6" 9'-3" 11'-11¼" 5'-6" 9'-6" 5'-6" 34'-8" 32'-5¼" Weight of Engine 277,800 Weight of Tender Loaded 145,600 Total Weight 423,400	'13	214.21 (77.1%)	63.59 (22.9%)	2.29	16"	63	16.49	16.5	11.3	1595	174			199						326					6131, 33, 42, 45	19 20 21 23 25 29	**H5-LA** TYPE I (7500 GAL. TANK)
H5-LA TYPE III (10000 GAL. TANK)	 10,000 Gallons 16 Tons 11.90 26.29 26.29 26.29 26.29 21.85 22.94 22.94 22.94 22.94 8'-11" 5'-6" 5'-6" 5'-6" 9'-3" 11'-10½" 5'-10" 11'-10" 5'-10" 34'-8" 35'-4½" Weight of Engine 277,800 Weight of Tender Loaded 183,500 Total Weight 461,300	'13	213.21 (77.1%)	63.59 (22.9%)	2.29	16"	63	16.49	16.5	11.3	1595	174			199						326					6141, 47	9 15 21	**H5-LA** TYPE III (10,000 GAL. TANK)
H5-L TYPE I (7500 GAL. TANK)	 7,500 Gallons 12 Tons 11.15 26.33-26.33-26.33-26.33 21.05 18.81 18.81 18.81 18.81 8'-11" 5'-6" 5'-6" 5'-6" 8'-3" 10'-8" 5'-10" 7'-9" 5'-10" 34'-8" 30'-1" Weight of Engine 275,700 Weight of Tender Loaded 150,500 Total Weight 426,200	'14	213.62 (77.5%)	62.08 (22.5%)	2.29	16"	63	16.49	16.5	11.3	1589	174			199						326					6000, 02, 28, 35, 36	7 27 8 34 10 35 11 38 20 39 22	**H5-L** TYPE I (7500 GAL. TANK)
H5-L TYPE III (8000 GAL. TANK)	 8,000 Gallons 12 Tons 11.5 26.33-26.33-26.33-26.33 21.05 20.25 20.25 20.25 20.25 8'-11" 5'-6" 5'-6" 5'-6" 9'-3" 11'-8" 6'-0" 9'-0" 6'-0" 34'-8" 32'-8" Weight of Engine 275,700 Weight of Tender Loaded 162,000 Total Weight 437,700	'14	213.22 (77.5%)	62.08 (22.5%)	2.29	16"	63	16.49	16.5	11.3	1589	174			199						326					6016	31	**H5-L** TYPE III (8000 GAL. TANK)
H5-O TYPE I (7500 GAL. TANK)	 7,500 Gallons 12 Tons 11.4 26.91 26.91 26.91 26.91 18.6 18.81 18.81 18.81 18.81 8'-11" 5'-6" 5'-6" 5'-6" 9'-3" 10'-8" 5'-10" 7'-9" 5'-10" 34'-8" 30'-1" Weight of Engine 275,300 Weight of Tender Loaded 150,500 Total Weight 425,800	'14	213.22 (77.4%)	62.08 (22.6%)	2.29	16"	63	16.49	16.5	11.3	1589	173			199						326					6702, 17	7 31	**H5-O** TYPE I (7500 GAL. TANK)
H5-O TYPE-II TYPE-III (8000 GAL. TANK BOOSTER)	 8,000 Gallons-12 Tons ○ 11.4 26.91-26.91-26.91-26.91 18.6 + 13.1 26.66-26.66-26.66-26.66 21.35 20.25 20.25 20.25 20.25 8'-11" 5'-6" 5'-6" 5'-6" ○9'-3" +9'-10" ○11'-8" +11'-1" 6'-0" 9'-0" 6'-0" ○34'-8" +35'-3" ○32'-8" +32'-1" ○ Weight of Engine 275,300 Weight of Tender Loaded 162,000 Total Weight 437,300 + Weight of Engine 282,200 Weight of Tender Loaded 162,000 Total Weight 444,200	'14 '14	213.22 (77.4%) 220.9 (78.3%)	62.08 (22.6%) 61.30 (21.7%)	2.29 2.29	16" 16"	63 63	16.49 16.49	16.5 16.5	11.3 11.3	1589 1589	173 178			199 199						326 326					○-6047, 48, 55, 56, 59, ○-6704, 06, 09, 13 + 6710	○ 7 + 15 ○ 9 + 16 ○ 20 ○ 26 ○ 27 ○ 30	**H5-O** TYPE II TYPE III (8000 GAL. TANK BOOSTER)
H5-T	 17'-2⅜" 10,000 Gallons 16 Tons 12.25 26.94-26.94 26.94 26.94 22.75 25.04 25.04 25.04 25.04 9'-3" 5'-6" 5'-6" 5'-6" 9'-3" 11'-6½" 6'-6" 11'-2" 6'-6" 35'-0" 35'-8½" Weight of Engine 285,500 Weight of Tender Loaded 200,300 Total Weight 485,800	'16	222.13 (77.8%)	63.37 (22.2%)	2.21	16"	63	16.49	16.5	11.3	1593	178	248	230	199	226	903	56.7	406	377	326	370	1479	2092	.00703	6079, 89	11 21	**H5-T**

75,500
78,000
35,500

8,800
8,000
6,800

6,450
5,620
2,070

7,860
7,200
5,060

90,000
78,360
68,360

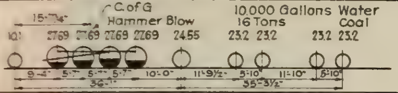
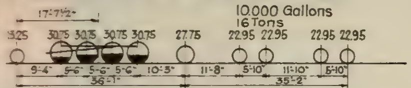
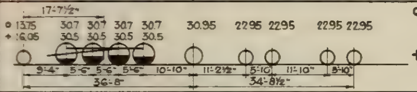
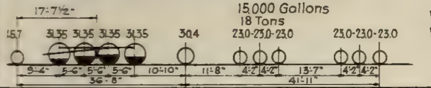
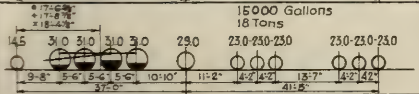
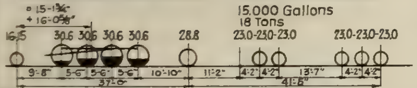
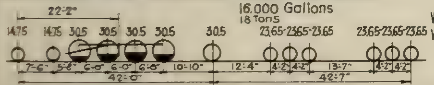
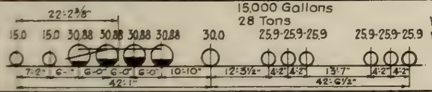
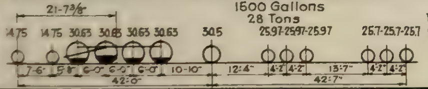
7,500
6,550
4,050

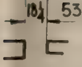
9,000
2,725
1,725

BIG FOUR FREIGHT LOCOMOTIVES

TABLE XIV

④

Class of Locomotive	Wheel Loads, Wheel Spacing and Location of Resultant of Counter Weight Hammer Blows.	Date	Weights of Engine (Kips)		Freq. of Loc. Springs	Drivers			Speed at 1 R.P.S.		Wght. of Recipro. Parts	Wght Eng. / Rec. Parts	Recip. Weights Balanced						Hammer Blow at 1 R.P.S.						Total H B / Wght Eng	Locomotives used in Tests		Class of Locomotive
			Live	Dead		Crank Pin Rad.	Diam. (ins.)	Circum. (Ft.)	F.P.S.	M.P.H.			Driver				Total	%	Driver (one side)				Total			Engine No	On Span No	
													1	2	3	4			1	2	3	4	One Side	Eng.				
H6-A	 15'-7¾" C of G Hammer Blow 10,000 Gallons Water 16 Tons Coal 10.1 27.69 27.69 27.69 27.69 24.55 23.2 23.2 23.2 23.2 9'-4" 5'-7" 5'-7" 5'-7" 10'-0" 11'-9½" 5'-10" 11'-10" 5'-10" 36'-1" 35'-3½" Weight of Engine 290.800 Weight of Tender Loaded 185,600 Total Weight 476,400	'18	224.87 (77.3%)	65.93 (22.7%)	2.25	15"	63	16.49	16.5	11.3	1743	172	371	310	-63	371	989	56.7	567	473	-96	567	1511	2136	.00736	6096, 97, 99, 6101. 06, 08, 12	1 18 2 20 3 21 5 7 9	**H6-A**
H7-E **TYPE I** ORIGINAL	 17'-7½" 10,000 Gallons 16 Tons 13.25 30.75 30.75 30.75 30.75 27.75 22.95 22.95 22.95 22.95 9'-4" 5'-6" 5'-6" 5'-6" 10'-3" 11'-8" 5'-10" 11'-10" 5'-10" 36'-1" 35'-2" Weight of Engine 328,000 Weight of Tender Loaded 183,600 Total Weight 511.600	'20	263.97 (80.5%)	64.03 (19.5%)	2.07	15"	63"	16.49	16.5	11.3	2015	163	313	252	252	320	1147	56.4	479	386	386	490	1741	2455	.00748	6151, 63, 91, 98	12 21 27 30	**H7-E** **TYPE I** ORIGINAL
ORIGINAL **H7-E** ∘TYPE II (BOOSTER) +TYPE III (BOOSTER AIR PUMP)	 17'-7½" ∘ 13.75 30.7 30.7 30.7 30.7 30.95 22.95 22.95 22.95 22.95 + 16.05 30.5 30.5 30.5 30.5 9'-4" 5'-6" 5'-6" 5'-6" 10'-10" 11'-2½" 5'-10" 11'-10" 5'-10" 36'-8" 34'-8½" ∘ Weight of Engine 334.900 Weight of Tender Loaded 183,600 Total Weight 518.500 + Weight of Engine 335.900 Weight of Tender Loaded 183.600 Total Weight 519.500	'20 '20	272.3 (81.3%) 273.3 (81.4%)	62.60 (18.7%) 62.60 (18.6%)	2.07 2.07	15" 15"	63 63	16.49 16.49	16.5 16.5	11.3 11.3	2015 2015	166 167	313 313	252 252	252 252	320 320	1147 1147	56.4 56.4	479 479	386 386	386 386	490 490	1741 1741	2455 2455	.00733 .00731	∘6168, 70 +6179	∘12 ∘+20	ORIGINAL **H7-E** ∘TYPE II (BOOSTER) +TYPE III (BOOSTER AIR PUMP)
H7-E **TYPE V** (LONG TENDER BOOSTER F.W. HEATER)	 17'-7½" 15,000 Gallons 18 Tons 15.7 31.35 31.35 31.35 31.35 30.4 23.0-23.0-23.0 23.0-23.0-23.0 9'-4" 5'-6" 5'-6" 5'-6" 10'-10" 11'-8" 4'-2" 4'-2" 13'-7" 4'-2" 4'-2" 36'-8" 41'-11" Weight of Engine 343,100 Weight of Tender Loaded 276,000 Total Weight 619.100	'20	280.5 (81.8%)	62.60 (18.2%)	2.07	15"	63	16.49	16.5	11.3	2015	170	313	252	252	320	1147	56.4	479	386	386	490	1741	2455	.00713	6153, 56, 58, 59	9 20 25 26 27	**H7-E** **TYPE V** (LONG TENDER BOOSTER F.W. HEATER)
H10-A ∘TYPE I +TYPE II ×TYPE III	 ∘ 17'-6⅝" + 17'-8⅞" × 18'-4⅛" 15000 Gallons 18 Tons 14.5 31.0 31.0 31.0 31.0 29.0 23.0-23.0-23.0 23.0-23.0-23.0 9'-8" 5'-6" 5'-6" 5'-6" 10'-10" 11'-2" 4'-2" 4'-2" 13'-7" 4'-2" 4'-2" 37'-0" 41'-5" Weight of Engine 335,000 Weight of Tender Loaded 276,000 Total Weight 611,000	'22 '23 '23	271.30 (81.0%)	63.70 (19.0%)	2.25 2.25 2.25	∘15" +15" ×15"	63 63 63	16.49 16.49 16.49	16.5 16.5 16.5	11.3 11.3 11.3	1833 1899 1894	183 177 177	184 160 167	172 177 90	56 149 161	175 156 174	587 642 592	32.0 33.9 31.6	281 245 256	263 271 138	86 228 246	268 239 266	898 983 906	1270 1390 1280	.00379 .00415 .00382	∘ 4, 5, 13, 15, 20, 25, 29, 42, 48 + 81, 97, 134, 135, 137, 140, 146, 148, 149, 161, 152, 154, 155, 156, 158, 160, 169 × 150, 170, 171, 172, 174, 178	∘+×4 +17 ∘+×6 ∘+20 ∘7 ×21 ∘+9 ∘+×23 +×15 ∘+26 +16 ∘+27	**H10-A** ∘TYPE I +TYPE II ×TYPE III
H10-B ∘TYPE I +TYPE II	 ∘ 15'-1¾" + 16'-0⅝" 15,000 Gallons 18 Tons 16.5 30.6 30.6 30.6 30.6 28.8 23.0-23.0-23.0 23.0-23.0-23.0 9'-8" 5'-6" 5'-6" 5'-6" 10'-10" 11'-2" 4'-2" 4'-2" 13'-7" 4'-2" 4'-2" 37'-0" 41'-5" Weight of Engine 334.500 Weight of Tender Loaded 276,000 Total Weight 610.500	'24 '24	268.61 (80.3%)	65.84 (19.7%)	2.25 2.25	∘15" +15"	63 63	16.49 16.49	16.5 16.5	11.3 11.3	1858 1813	180 184	234 172	212 151	-124 -134	228 183	550 372	29.6 20.5	358 263	324 231	-190 -206	348 280	840 568	1188 803	.00342 .00242	∘214, 15, 17, 19, 20, 21, 22, 23, 24, 226, 27, 28, 29, 32, 35, 39 +322, 329, 330, 360	∘7 ∘28 ∘+8 ∘34 ∘9 ∘35 ∘+15 ∘+38 ∘16 ∘21	**H10-B** ∘TYPE I +TYPE II
L2-B	 22'-2" 16,000 Gallons 18 Tons 14.75 14.75 30.5 30.5 30.5 30.5 30.5 23.65-23.65-23.65 23.65-23.65-23.65 7'-6" 5'-8" 6'-0" 6'-0" 6'-0" 10'-10" 12'-4" 4'-2" 4'-2" 13'-7" 4'-2" 4'-2" 42'-0" 42'-7" Weight of Engine 364,000 Weight of Tender Loaded 292,300 Total Weight 656,300	'29	293.25 (80.6%)	70.75 (19.4%)	2.25	15"	69	18.05	18.05	12.3	2047	178	192	238	234	191	855	41.7	294	364	358	292	1308	1844	.00507	6200, 01, 02, 03, 04, 05, 06, 07, 08, 6209, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 24	4 20 27 38 6 22 28 39 7 23 30 8 24 35 9 25 36 14 26 37	**L2-B**
L2-D	 22'-2⅜" 15,000 Gallons 28 Tons 15.0 15.0 30.88 30.88 30.88 30.88 30.0 25.9-25.9-25.9 25.9-25.9-25.9 7'-2" 6'-" 6'-0" 6'-0" 6'-0" 10'-10" 12'-3½" 4'-2" 4'-2" 13'-7" 4'-2" 4'-2" 42'-1" 42'-6½" Weight of Engine 367.000 Weight of Tender Loaded 309,600 Total Weight 676.600	'29	295.55 (80.5%)	71.45 (19.5%)	2.25	15"	69	18.05	18.05	12.3	2062	178	261	244	235	258	998	48.4	397	373	360	395	1527	2163	.00587	6225, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49	4 22 28 38 6 23 30 39 7 24 34 8 25 35 9 26 36 20 27 37	**L2-D**
L2-C	 21'-7⅜" 1500 Gallons 28 Tons 14.75 14.75 30.63 30.63 30.63 30.63 30.5 25.97-25.97-25.97 25.7-25.7-25.7 7'-6" 5'-8" 6'-0" 6'-0" 6'-0" 10'-10" 12'-4" 4'-2" 4'-2" 13'-7" 4'-2" 4'-2" 42'-0" 42'-7" Weight of Engine 365,000 Weight of Tender Loaded 310,000 Total Weight 675,000	'29	293.8 (80.5%)	71.2 (19.5%)	2.25	15"	69"	18.05	18.05	12.3	2057	177	194	239	235	190	858	41.7	296	365	359	290	1310	1854	.00508	2854, 57, 59, 64, 79, 80, 82, 87, 91	9 20	**L2-C**



50½"

284300
67700
352000

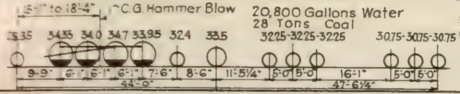
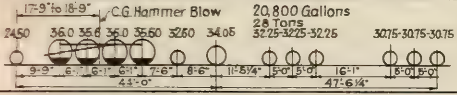
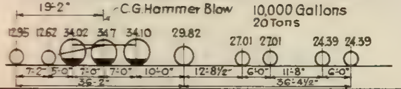
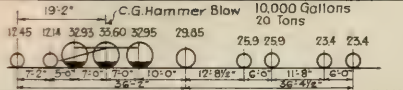
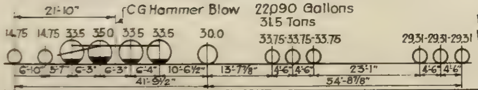
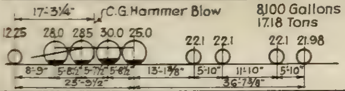
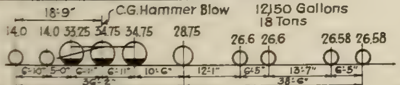
PS.-14.1 M.1

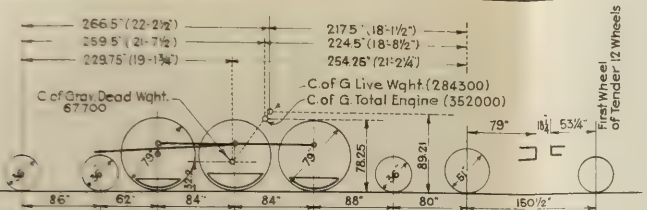
.414=1691

L
C

FOREIGN LOCOMOTIVES

TABLE XIV

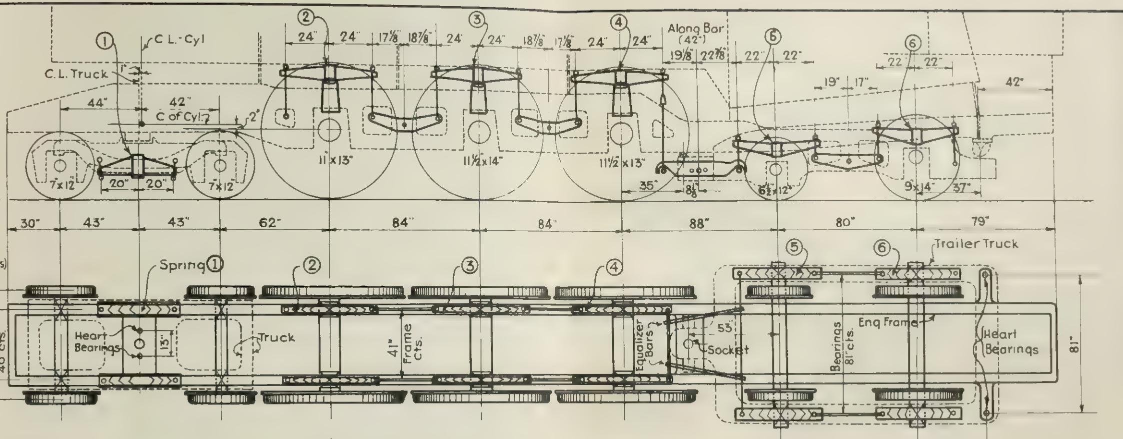
Class of Locomotive	Wheel Loads, Wheel Spacing and Location of Resultant of Counter Weight Hammer Blows.	Date	Wghts. of Engine (Kips)		Freq. of Loc. Springs	Drivers			Speed at 1-R.P.S.		Wght. of Recipro. Parts	Wght. Eng. / Rec. Parts	Recip. Weights Balanced						Hammer Blow at 1 R.P.S.						Total H.B. / Wght Eng.	Locomotives used in Tests		Class of Locomotive
			Live	Dead		Crank Pin Rad.	Diam (ins)	Circum. Ft.	F.P.S.	M.P.H.			Driver 1	Driver 2	Driver 3	Driver 4	Total	%	Driver (One Side) 1	2	3	4	Total One Side	Total Eng.		Engine No.	On Span No.	
ERIE S2	 15'-1" to 18'-4" C.G. Hammer Blow 20,800 Gallons Water 28 Tons Coal 25.35 34.35 34.0 34.7 33.95 32.4 33.5 32.25-32.25-32.25 30.75-30.75-30.75 9-9" 6-1" 6-1" 6-1" 7-6" 8-6" 11-5¼" 5-0" 5-0" 16-1" 5-0" 5-0" 44'-0" 47'-6¼" Wght of Eng. 475,500 Wght of Ten Loaded 378,000 Tot Wght 835,500	'28				16	70	18.33	18.33	12.5	2871 2835 2873 2835 2880 2937 2908	159 161 159 161 159 156 157	346 319 314 349 360 327 343	235 248 274 267 254 230 357	-238 -237 -193 + 72 +280 -236 +146	332 296 304 333 325 314 335	675 632 704 1015 659 635 1181	24.0 28.3 24.3 35.8 22.9 21.6 41.8	567 523 515 572 590 536 562	385 406 449 328 416 367 585	-390 -379 -316 +118 -459 -387 +239	544 485 498 546 533 515 649	1106 1035 1146 1564 1080 1031 1935	1563 1463 1620 2210 1527 1458 2736	.00334 .00312 .00346 .00472 .00326 .00312 .00585	3325. 26. 27. 34, 38, 45, 87	8	**ERIE S2**
ERIE S4	 17'-9" to 18'-9" C.G. Hammer Blow 20,800 Gallons 28 Tons 24.50 36.0 35.6 36.0 35.60 32.60 34.05 32.25-32.25-32.25 30.75-30.75-30.75 9-9" 6-1" 6-1" 6-1" 7-6" 8-6" 11-5¼" 5-0" 5-0" 16-1" 5-0" 5-0" 44'-0" 47'-6¼" Wght. of Eng. 468,800 Wght of Ten. Loaded 378,000 Tot. Wght. 846,800	'30				16	70	18.33	18.33	12.5	2909 2862 2855 2859 2894	161 163 164 164 162	342 329 355 423 383	371 387 390 336 354	-132 + 99 +142 - 56 +158	382 397 346 443 398	963 1212 1232 1146 1293	33.7 41.6 43.3 39.6 45.2	560 539 582 693 628	608 634 639 551 580	-216 +162 +232 - 91 +259	626 651 565 726 653	1578 1986 2018 1879 2120	2231 2808 2853 2657 2998	.00497 .00600 .00608 .00566 .00639	3389, 90, 96, 3400, 03	8	**ERIE S4**
ERIE K5	 19'-2" C.G. Hammer Blow 10,000 Gallons 20 Tons 12.95 12.62 34.02 34.7 34.10 29.82 27.01 27.01 24.39 24.39 7'-2" 5'-0" 7'-0" 7'-0" 10'-0" 12'-8½" 6'-0" 11'-8" 6'-0" 36'-2" 36'-4½" Weight of Engine 316,450 Weight of Tender Loaded 205,620 Total Weight 522,070					14"	79"	20.68	20.68	14.1	1893 1780	172 178	346 302	316 418	316 314		978 1034	53.3 58.0	494 458	452 598	452 449	- -	1398 1505	1977 2128	.00625 .00673	2924. 27	8	**ERIE K5**
ERIE K5A	 19'-2" C.G. Hammer Blow 10,000 Gallons 20 Tons 12.45 12.14 32.93 33.60 32.95 29.85 25.9 25.9 23.4 23.4 7'-2" 5'-0" 7'-0" 7'-0" 10'-0" 12'-8½" 6'-0" 11'-8" 6'-0" 36'-2" 36'-4½" Weight of Engine 307,860 Weight of Tender Loaded 197,200 Total Weight 505,060					14"	79"	20.68	20.68	14.1	1819	169	323	326	303	-	952	52.3	462	466	459	-	1387	1961	.00638	2943	8	**ERIE K5A**
P.R.R. M1A	 21'-10" C G Hammer Blow 22,090 Gallons 31.5 Tons 14.75 14.75 33.5 35.0 33.5 33.5 30.0 33.75-33.75-33.75 29.31-29.31-29.31 6'-10" 5'-7" 6'-3" 6'-3" 6'-4" 10'-6½" 13'-7⅞" 4'-6" 4'-6" 23'-1" 4'-6" 4'-6" 41'-9½" 54'-8⅞" Wght. of Eng. 390,000 Wght of Ten Loaded 378,360 Tot. Wght. 768,360	'30	323.9 (83.0%)	66.1 (17.0%)		15"	72"	18.85	18.85	12.8	1807	216	214	214	214	214	856	47.4	327	327	327	327	1308	1850	.00474	6778, 79, 84, 86, 89, 92, 93, 96	32 33	**P.R.R. M1A**
P.R.R. H10S	 17'-3¼" C.G. Hammer Blow 8,100 Gallons 17.18 Tons 12.25 28.0 28.5 30.0 25.0 22.1 22.1 22.1 21.98 8'-9" 5'-8½" 5'-7½" 5'-8½" 13'-1⅜" 5'-10" 11'-10" 5'-10" 25'-9½" 36'-7⅜" Weight of Engine 247,500 Weight of Tender Loaded 176,550 Total Weight 424,050	'28	209.3 (84.6%)	38.2 (15.4%)		14"	62"	16.23	16.23	11.07	1358	182	226	226	226	226	904	66.6	323	323	323	323	1292	1830	.00739	7024, 8594, 98, 8809, 11, 13, 51 9418 9918	32 33 34 39	**P.R.R. H10S**
P.R.R. K4S	 18'-9" C.G. Hammer Blow 12,150 Gallons 18 Tons 14.0 14.0 33.25 34.75 34.75 28.75 26.6 26.6 26.58 26.58 6'-10" 5'-0" 6'-1" 6'-11" 10'-6" 12'-1" 6'-5" 13'-7" 6'-5" 36'-2" 38'-6" Weight of Engine 319,000 Weight of Tender Loaded 212,725 Total Weight 531,725	'29	267.5 (83.8%)	51.5 (16.2%)		14"	80"	20.9	20.9	14.3	1484	215	286	286	286		858	57.8	400	400	400		1200	1694	.00531	5405, 20, 21, 24, 27, 72, 75, 77, 78, 80, 81, 90, 91, 92, 93, 96, 99	32 33	**P.R.R. K4S**

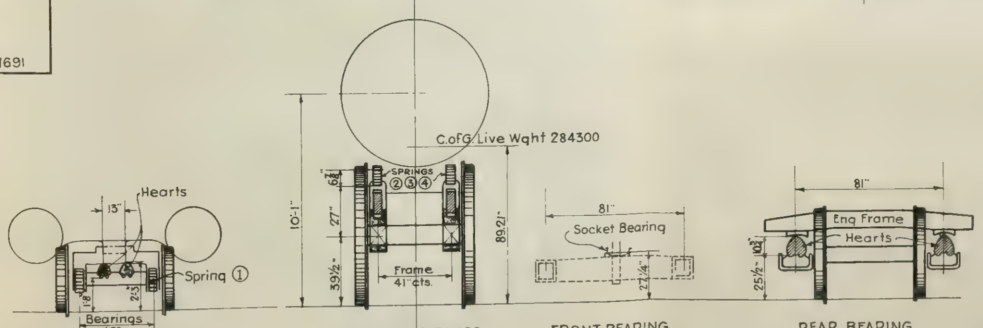


Live Weight	25150	25150	50100	45400	50000	42000	46500	284300	80.8%
Dead Weight	7350	7350	12200	17000	12300	3500	8000	67700	19.2%
Total	32500	32500	62300	62400	62300	45500	54500	352000	(Official Wghts)

Recip Weights (One Side)		Revolving Weights: Driver	Front	Interm	Rear		
Piston	416	Main Rod Back ½		581		Crank Pin Rad = 14"	
Piston Rod	349	Ec Crank Equiv		75		Cyl – cts.	89"
X-head Shoe & Pin	754	Side Rods	190	556	176	Side Rod cts.	75"±
Union Link	30	Total at	—	—	—	Diam. Drivers	79"
Main Rod Front ½	422	Crank Pin	190	1212	176	Circum. Drivers	20.7'
Total	1971	Scale Wghts. at Crank Pin	452	1519	452	Veloc.-1 R.P.S.-	20.7 F.P.S.-14.1 M.P.H
		Aver. Amt Rec Parts Balanced	262	307	276	Total - 845 - $\frac{845}{1971}$ = 42.8%	
		Hammer Blow at 1 R.P.S.	372	435	392	Total - One Side = 1199 Total - Engine = 1199 x 1.414 = 1691	

Spring No	Length	Make up	Height: Free	Height: Loaded	Deflec	Working Load	Time of Vibration	Freq.	Load per inch Deflection
1	40"	24-5"x7/16"	14.25	12.0	2.25	33600	.480	2.08	14920
2	48"	16-6"x½"	9	6.375	2.625	24600	.519	1.93	9370
3	48"	16-6"x½"	9	6.375	2.625	24600	.519	1.93	9370
4	48"	16-6"x½"	9	6.375	2.625	24600	.519	1.93	9370
5	44"	14-6"x½"	11.875	9.50	2.375	21250	.493	2.03	8960
6	44"	16-6"x½"	12.875	10.50	2.375	23850	.493	2.03	10050





LIVE WEIGHT BEARING OVER ENGINE TRUCK

FRAME BEARINGS OVER DRIVERS

FRONT BEARING ON TRAILER TRUCK

REAR BEARING TRAILER TRUCK

SPRING ARRANGEMENT AND COUNTER BALANCING CLASS J1D LOCOMOTIVE

Fig. 26

The counterbalancing of Company owned and Pennsylvania locomotives is the average of the class. The overbalances on the Erie engines apparently were not adjusted so that each locomotive has a different hammer blow. The amount of the reciprocating parts which have been counterbalanced runs from 20.5 per cent for the Big Four H10-B, Type I locomotive, to 66.6 per cent for the Pennsylvania H10-S locomotive. While the percentage for this latter engine is high, its actual hammer blow of 1830 lb. is not large, as its reciprocating parts are comparatively light in weight.

The general arrangement of the spring rigging of a modern locomotive is illustrated in Fig. 26. This drawing also shows the weight of the rotating and reciprocating parts, the counterbalancing and the distribution of the live and dead weights.

Appendix B

SPAN DIAGRAMS AND TEST DATA

In the following pages there will be found a drawing of each span tested, together with test data given in tabular form. One or more diagrams, showing a comparison of the measured and theoretical oscillations, are given for each bridge.

When there was some peculiarity of the span which might have influenced the tests or afforded an explanation of some fancied discrepancy in the results, it has been mentioned in the short description accompanying the drawings and tables.

The drawings give the general dimension of the span, and the gross section of the members. Information as to the type of bearing, deck construction, location of rail joints, and spacing of the position trips, is given. The design load and stresses, weights, and both the theoretical and observed deflection constants are also shown.

The information obtained from the tests is given in the tables of test data. The first eight columns need no explanation. The wheel spacing, weight on axles, and the counterbalancing for each class of locomotive will be found in Appendix A. For the short spans in which the maximum deflection occurs under the engine only, the tender weight is the nominal weight of the fully loaded tender. On longer spans the approximate tender load, as obtained from the coal and water reports, is given. When tests were made with a movement of traffic in both directions, it will usually be found that the tender weights of trains in one direction may be quite a little heavier or lighter than those of the trains in the opposite direction.

The distance P was scaled from each record, and represents the distance of the first wheel of the locomotive from the approach end of the span, at the time maximum deflection occurred. This distance varies with the tender and car loading, and the average value, obtained for any one class of locomotive, was used as representing the position of the load when computing the theoretical deflection.

The live load deflection, D, is the maximum deflection which occurred at some point on the span, usually the center, when the locomotive had traveled the distance P. It was scaled from the crawl deflection line which had been constructed as outlined in Section f of Part IV. The scaled deflections were corrected for variation in spring and wire tension.

From the true deflection, D, under some known loading, the deflection factor of the span was found, and the deflection under any other loading, was then estimated, as explained in Section c of Part IV. Having this factor, the dead load deflection, d, and the deflection D_h, due to the hammer blow at 1 r.p.s., acting statically at the center of the span, were then computed. Other useful deflection constants were derived; these being the deflection per 1000 lb. per ft. of track, deflection per 1000 lb. stress, and the deflection produced by a centrally placed concentrated load of 1000 lb.

The equivalent uniform live load as given was obtained by dividing the deflection, D, by the deflection per 1000 lb. per ft. It represents the uniformly distributed load which would produce the same deflection as the test load.

From the dead, live, and concentrated load deflections, the natural loaded frequency, n, was computed for each test. For spans more than 100 ft. in length, the equation $n = \sqrt{\frac{12}{d + D}}$, was used. For shorter spans the several concentrations were taken into account by equation (3), page 23. The frequencies shown in the tables were not corrected for damping, but for the shorter spans this correction was made, and the corrected frequency was used in preparing the various diagrams of the theoretical oscillations and magnifiers.

The speed, as given in miles per hour and revolutions per second, N, of the locomotive drivers, was taken from the records. The distance, H, as given in the next column, has but little significance, except at or near synchronous speed. It represents the position of the center of gravity of the hammer blow, in reference to the center of the span, at the instant the maximum static deflection occurred. On the wheel spacing diagrams in Appendix A, the distance, from wheel No. 1 to the center of gravity of the hammer blow is given and if this distance be Y, $H = P - \left(\frac{L}{2} + Y\right)$.

The oscillations were scaled from the record and corrected for variation in wire tension, and the next column gives the deflection due to the hammer blow operating at N, r.p.s. and acting statically, or $D_h N^2$. The values for the dynamic magnifier, k, are obtained by dividing the oscillation h, by $D_h N^2$. As expected, the maximum values of k are found near the synchronous speed, unless the oscillations at that speed, have been affected by some form of external damping, such as locomotive spring action. High values at low speeds are sometimes found, but they are unimportant, as they are often based on free rather than forced vibrations and, in a sense, are fictitious. Occasionally, however, at or near half synchronous speed, they do represent the magnification of the hammer blow, when its frequency is about one-half of the natural frequency of the bridge. Span No. 6 seemed to be especially susceptible to this effect.

The impact values shown are found by dividing the oscillation, h, by the static deflection, D. They are given simply as a matter of information, and do not represent in any way the amount of impact to be expected on that span under the condition of loading in which we are interested, that is, capacity loading.

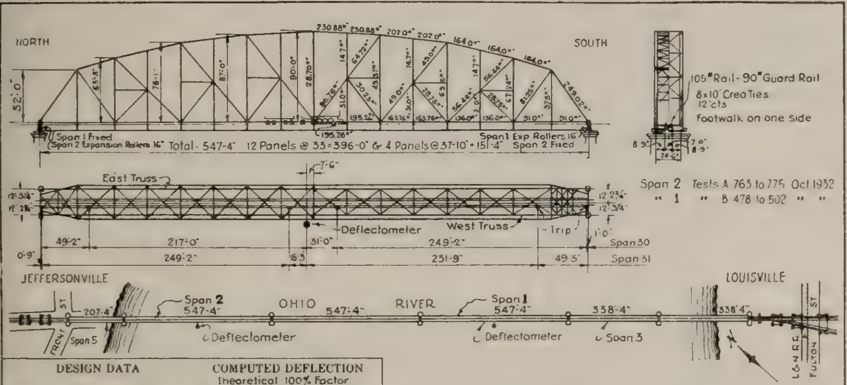
The last four columns in the tables give the computed, and not measured, stresses, which are shown only for the purpose of indicating the relation of the test load to the load capacity of the span. The dead load stress, for girders, is the tension flange stress, and was calculated from the net Moment of Inertia of the section. For trusses it is the lower chord stress computed from the net section of the chord. The live load stress may be found by using the dead load per foot, the E.U.L.L., and the dead load stress, or by using the live load deflection D, and the deflection constant for 1000 lb. stress in the flange or chord.

SPANS NOS. 1 and 2

Single track riveted through truss spans, 547 ft., 4 in. long, 90 ft. center to center of chords, weighing 4,698,000 lb. each. The trusses are of silicon steel, the floor system being of carbon steel. See Fig. 27.

They were tested with a single engine, Class H6-A, which has the comparatively large hammer blow of 2140 lb. at 1 r.p.s. As no train was used, the E.U.L.L. is quite light, being only 1600 lb. per ft.

The natural frequency of vibration of the span under this loading is 1.66 per second. Unfortunately no run was made at this exact speed, the nearest being tests B-500, at 1.59 r.p.s.; B-487, at 1.65 r.p.s.; and B-499, at 1.73 r.p.s. From these three tests the lowest value of the damping constant, *p*, was found to be .016. In Fig. 28, are plotted the observed oscillations and dynamic magnifiers, and their theoretical values, based on the damping constant *p*, of .016, the actual values being in close agreement with the theoretical. On spans of low frequency a small variation in speed either way from synchronism, results in a large decrease in magnification of the hammer blow. For this locomotive, at 1.66 r.p.s., the synchronous speed is 18.75 m.p.h. An increase or decrease in speed of only 1 m.p.h. would reduce the oscillations about one-half.



DESIGN DATA	
Date 1928	Spec. 1917
Material	Silicon & OH Steel
Loading E-65	E.U.L.L. 6675
Flange Stress	D.L. 11520
(Tens. N. Sec.)	L.L. 8900
	Imp. 1780
	Total 22200
Gross M. of I. at Center	
Weight Steel per Ft.	8000
Weight Deck per Ft.	580
Total per Ft.	8580
Total for Span	4697500

COMPUTED DEFLECTION Theoretical 100% Factor	
For 1000 Lbs. per Ft. Trk.	.527"
For 1000 Lbs. at Center	.00185"
D.L. Deflection	4 518
D.L. Frequency	1 63

COMPUTED FROM TESTS	
Deflec. 1000 Lbs. per Ft. Trk.	.426"
Deflec. 1000 Lbs. at Center	.00150"
Deflec. D.L.	3.655
Frequency D.L.	1.81

$$\frac{\text{Observed Defl.}}{\text{Computed Defl.}} = .809$$

LOCOMOTIVES USED IN TESTS

Class of Engines										
Engines per class										
Tests per class										
Class of Engines	Span 2 H6A	Span 1 H6A								
Engines per class	1	1								
Tests per class	13	25								

SPANS 1 & 2
L & J Bridge
2ND & 4TH Spans Single Track
547'-4" Thru Trusses
Riveted
Trusses - Silicon Steel
Floor - Carbon Steel

Fig. 27

We have here a fine illustration of the damping effect of end friction. These spans are exactly alike, both having 16-inch expansion rollers supposedly in first class condition, and it was to be expected that they would act in a similar manner, but when the tests were examined it was found that the deflections and oscillations in Span No. 2 were considerably smaller than in Span No. 1. It so happened that one member of the party measured the movement of the expansion end on Test B-481, Span No. 1, and the movement was 7/16 inch, corresponding to a unit chord stress of 1940 lb. On Test A-763, Span No. 2, the chord elongation was only 3/16 inch, denoting a stress of only 850 lb. It will be seen in the tables of test results that with the exception of the first three runs, A-763, 764, 765, the deflections are not much more than 80 per cent of those for Span No. 1. In the first three tests, the speed was close enough to synchronism to give oscillations of sufficient magnitude to break loose whatever had been holding the rollers; this is quite clearly shown in the crawl deflection diagrams.

The larger end bearing friction in Span No. 2 not only caused a decrease in deflection, but also damped the oscillations. If, however, we assume that the static hammer blow deflections, D_h, of the two spans are proportionate to their static deflections, we find that the values of the dynamic magnifier for the two spans are about the same, as will be seen in Fig. 28. While the oscillations are quite large, they are so slow that sufficient force to overcome spring friction is not developed, and the springs remained locked. With a frequency of 1.66, and assuming the low value of 0.10 for r, the oscillation, $h = \frac{r}{.1022\,N^2}$, would have to be 0.363 inch, while the maximum, at this speed, would have been about 0.17 inch.

From the average measured live load deflection in Span No. 1 of .677 inch, the computed dead load deflection is 3.655 inches, which gives a deflection factor of .809. The static hammer blow deflection, D_h, is .00322 inch, and the frequency of the unloaded span is 1.81.

These spans being of silicon steel, will have somewhat greater deflections and lower frequencies, when stressed to capacity, than similar spans of carbon steel, so that we may expect to find in them a somewhat smaller damping constant and a larger dynamic magnifier.

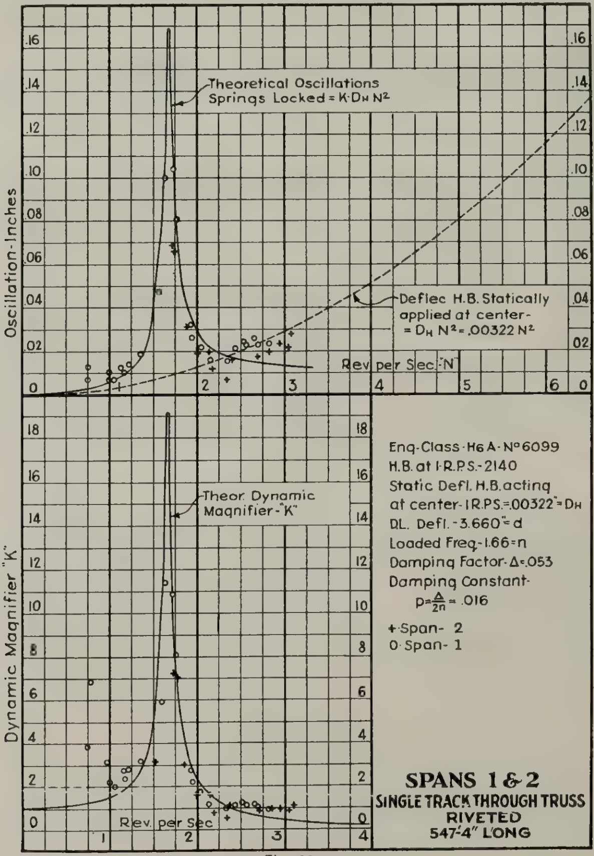


Fig.-28

TABLE XV

SPAN-4 LOUISVILLE BRIDGE 547'-4" THRU TRUSS SPAN- SINGLE TRK-SILICON STEEL Sheet 1 Span 1

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D	E U L L (Kips)	Loaded Frequency n	R P S N	M P H	Dist H (Ft)	Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact γ	D L	L L	Imp	Total
B-481	1	W	S	H6-A	6099	2140	2908	1856	None		329	689	1.61	166	.74	8.31	30	007	0018	3.88	10	11.52	217	02	1371
B-479	"	"	"	"	"	"	"	"	"	"	338	682	160	1.66	76	8 58	39	013	0019	6.84	1.9	"	215	.04	1371
B-483		"	"	"	"	"	"	"	"	"	331	691	162	166	.99	11 14	32	010	.0032	3.12	1.4	"	218	03	1373
B-482	"	"	"	"	"	"	"	"	"	"	320	662	155	166	100	11.19	21	.007	.0032	2 18	11	"	209	.02	1363
B-480	"	"	"	"	"	"	"	"	"	"	330	671	158	166	104	11 72	31	007	.0035	20	10	"	212	.02	1366
B-501	"	"	"	"	"	"	"	"	"	"	317	648	152	167	115	1295	18	.012	0043	279	19	"	204	04	1370
B-484	"	"	"	"	"	"	"	"	"	"	325	691	162	166	116	1308	26	.010	.0043	233	1.4	"	218	03	1373
B-485	"	"	"	"	"	"	"	"	"	"	321	695	163	166	121	1358	22	.014	.0047	291	2.0	"	219	.04	1375
B-486	"		"	"	"	"	"	"	"	"	313	691	162	166	136	1522	14	019	.0060	316	27	"	218	06	1376
B-500	"	"	"	"	"	"	"	"	"	"	299	669	1.57	167	159	1748	0	048	0081	592	72	"	210	15	1377
B-487	"	"	"	"	"	"	"	"	"	"	305	671	158	166	165	1807	6	100	0088	1136	149	"	212	32	1396
B-499	"	"	"	"	"	"	"	"	"	"	306	671	158	166	173	1934	7	.104	0096	1084	155	"	212	33	1397
B-488	"	"	"	"	"	"	"	"	"	"	314	.703	1.65	166	177	1976	15	081	0101	802	115	"	222	.26	1400
B-502	"	"	"	"	"	"	"	"	"	"	310	658	155	1.67	1.91	2145	11	.031	0118	263	47	"	208	10	1370
B-498	"	"	"	"	"	"	"	"	"	"	309	681	160	1.66	1.94	2179	10	026	.0121	2.15	3.8	"	215	08	1375
B-489	"	"	"	"	"	"	"	"	"	"	312	705	165	166	2.02	2236	13	.022	.0131	1.68	31	"	222	07	1381
B-490	"	"	"	"	"	"	"	"	"	"	311	682	160	166	2 12	2333	12	016	.0145	110	23	"	215	05	1372
B-491	"	"	"	"	"	"	"	"	"	"	308	678	160	166	2 33	2614	9	016	0175	91	21	"	214	.04	1370
B-492	"	"	"	"	"	"	"	"	"	"	313	.662	155	167	244	2738	14	.021	0192	109	32	"	209	.07	1368
B-494	"	"	"	"	"	"	"	"	"	"	304	678	160	166	252	2834	5	.024	0204	117	35	"	214	.07	1373
B-495	"	"	"	"	"	"	"	"	"	"	301	.669	157	167	255	2864	2	023	.0209	110	3.4	"	210	.07	1369
B-497	"	"	"	"	"	"	"	"	"	"	308	.669	157	167	265	2981	9	.026	.0226	115	39	"	210	08	1370
B-496	"	"	"	"	"	"	"	"	"	"	309	.671	158	166	267	30.00	10	023	0230	100	34	"	212	.07	1371
B-493	"	"	"	"	"	"	"	"	"	"	310	672	158	166	282	31.71	11	024	.0256	.93	42	"	212	.09	1373
							Average				314	677	159	156			15						214		

TABLE XVI

SPAN-2 LOUISVILLE BRIDGE - 547'-4" THRU TRUSS SPAN-SINGLE TRK-SILICON STEEL Sheet 1 Span 2

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No.	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D	E.U.L.L. (Kips)	Loaded Frequency n	R.P.S. N	M.P.H.	Dist H (Ft)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact γ	D L	L L	Imp	Total
A-763	1	W	N	H6A	6099	2140	2908	1856	None		303	.667	Not included in average		173	1955	4	068	0095	715	102				
A 764	"	"	"	"	"	"	"	"	"	"	313	.640			1.76	19.89	14	066	.0094	702	103				
A 765	"	"	"	"	"	"	"	"	"	"	318	.656			188	2124	19	.031	0110	282	47				
A-769	"	"	"	"	"	"	"	"	"	"	336	599			200	2260	37	.019	0112	161	32				
A-766	"	"	"	"	"	"	"	"	"	"	323	.574			214	2418	24	020	.0125	160	35				
A-767	"	"	"	"	"	"	"	"	"	"	328	570			217	2452	29	.011	0127	87	19				
A 774	"	"	"	"	"	"	"	"	"	"	330	560			233	2633	31	.006	0145	41	01				
A-768	"	"	"	"	"	"	"	"	"	"	330	567			237	2678	31	016	0152	105	28				
A-775	"	"	"	"	"	"	"	"	"	"	326	567			270	3051	27	017	0197	86	30				
A-770	"	"	"	"	"	"	"	"	"	"	329	568			283	3198	30	020	.0216	93	3.5				
A-773	"	"	"	"	"	"	"	"	"	"	323	567			295	3333	24	023	0235	98	41				
A-771	"	"	"	"	"	"	"	"	"	"	329	567	•		303	3424	30	.021	0248	.84	3.7				
A-772	"	"	"	"	"	"	"	"	"	"	331	562			307	3469	32	028	.0244	115	50				
							Average				325	.570					26								

NOTE.-Span 2 is a duplicate of Span 1 but owing to somewhat greater friction in its expansion bearings, deflections and oscillations are smaller than normal, except at speeds near synchronism - Tests A-763, 764 765, in which the larger oscillations seem to overcome the friction to a large extent. Assuming the normal Live Load deflec as 0.677 in (See Span 1) the Static HB deflection at 1RPS D_H = 00322" has been corrected by the ratio of the measured deflec of each test to 0.677 and the dynamic magnifier computed accordingly

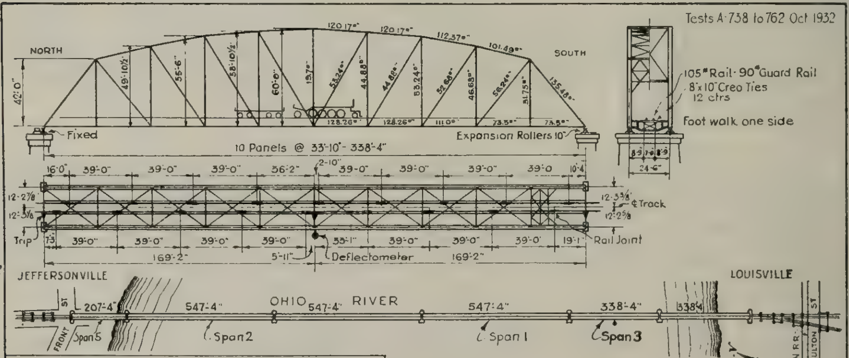
For Frequencies, Stresses etc - See Tests of Span 1

SPAN NO. 3

A single track riveted through truss span, 338 ft., 4 in. long, 60 ft. deep center to center of chords, weighing 1,834,600 lb. See Fig. 29.

This span was adjacent to and tested with Span No. 1, the runs, with the Class H6-A test engine being continuous. The average measured live load deflection was found to be 0.555 inch, from which we find the dead load deflection to be 1.192 inches, giving a deflection factor of .803. The static hammer blow deflection, D_h, is .00264 inch, and the unloaded frequency 3.17. The theoretical frequency of the bridge under this load is 2.61, but the actual frequency seems to be more nearly 2.55, or 98 per cent of the theoretical.

No tests were obtained at the exact synchronous speed, but from Test A-754, at 2.48 r.p.s., and Test A-755, at 2.72 r.p.s., the damping factor Δ, was found to be 0.1096, which gives for the damping constant, p, the value of .021. Using this value, the theoretical dynamic magnifiers and oscillations have been computed and these, with the actual values, are shown in Fig. 30. It will be seen that they agree closely. The oscillations are neither fast enough nor large enough to cause the locomotive springs to become active. They all fall below and to the left of the dotted line, which represents the magnitude of the oscillation, at any speed, necessary to overcome a spring friction equal to 15 per cent of the sprung weight. A comparatively light load was used in this test but with a heavier train the frequency of the vibrations would have been still lower, so that under no condition of loading need we look for any damping, from the locomotive springs, on such a span.



DESIGN DATA

Date 1928	Spec. 1917	
Material O H Steel		
Loading E-65	E.U.L.L.	7005
Flange Stress	D.L.	5900
(Tens. N. Sec.)	L.L.	7520
	Imp.	1560
	Total	14980
Gross M. of I. at Center		
Weight Steel per Ft.		4850
Weight Deck per Ft.		570
Total per Ft.		5420
Total for Span 1,834 600		

COMPUTED DEFLECTION
Theoretical 100% Factor

For 1000 Lbs. per Ft. Trk.	.2735
For 1000 Lbs. at Center	.00161
D.L. Deflection	1.485
D.L. Frequency	2.84

COMPUTED FROM TESTS

Deflec. 1000 Lbs. per Ft. Trk.	.2199
Deflec. 1000 Lbs. at Center	.00129
Deflec. D.L.	1.192
Frequency D.L.	3.17

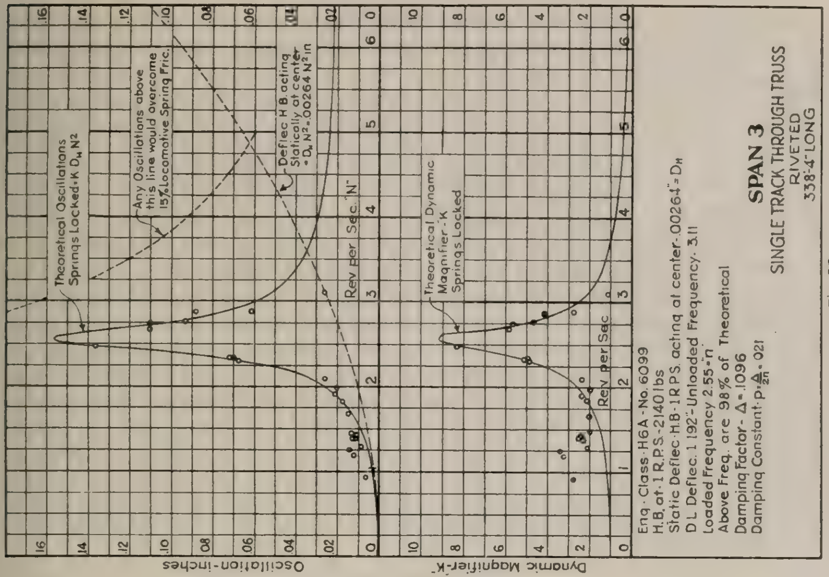
$\frac{\text{Observed Defl.}}{\text{Computed Defl}} = .803$

LOCOMOTIVES USED IN TESTS

Class of Engines										
Engines per class	–									
Tests per class	–									
Class of Engines	H6A									
Engines per class	1									
Tests per class	24									

SPAN 3
L & J Bridge
Fifth Span - Single Track
338'-4" Thru Truss
Riveted

Fig. 29



Eng. Class H6A - No. 6099
H.B. at 1 R.P.S. - 2140 lbs
Static Deflec. H.B. 1 R.P.S. acting at center .00264" = D_H
D.L. Deflec. 1.192" Unloaded Frequency 3.11
Loaded Freq. 2.55 ~n
Above Freq. are 98% of Theoretical
Damping Factor - Δ = .1096
Damping Constant $p = \frac{\Delta}{2\pi} = .021$

SPAN 3
SINGLE TRACK THROUGH TRUSS
RIVETED
338'-4" LONG

Fig 30

TABLE XVII

LOUISVILLE BRIDGE-338'-4" SINGLE TRACK-THRU TRUSS RIVETED-CARBON STEEL Sheet 1 Span 3

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1 RPS	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist P	Stat L L Defl Defl (ins) D	E.U.L.L. (Kips)	Loaded Frequency n	Speed R.P.S. N	Speed M.P.H.	Hammer Blow Dist H (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact γ	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A-741	I	W	S	H6A	6099	2140	290.8	185.6	None		212	546	248	263	092	1030	27	006	0022	273	11	5.90	270	03	863
A 739	-	.	-	-	..	-	-	..	-	-	208	.561	255	2.61	119	1345	23	.012	.0037	3.20	2.1	-	278	.06	8.74
A-743	.	-	-	-	-	.	-	.	-	-	213	.542	246	263	125	14.13	28	014	0041	341	26	-	268	.07	8.65
A-742	..	.	-		.	-	-	-	-	-	217	.560	255	2.61	129	1458	32	.009	.0044	2.05	1.6	..	278	.04	8.72
A-761	-	-	.	-	-	-	-	-	-	.	217				140	1582	32	.013	.0052	2.50		-			
A-744	..	.	-	.	-	.	-	..	..	..	217	.561	2.55	261	141	1593	32	012	.0053	226	21	.	278	06	874
A 740	..	-	-	..	..	-	..	..	.	..	214	.548	249	263	143	1616	29	.013	.0054	241	24	-	2.71	06	867
A-745	..	..	-	..	-	..	..	.	-	-	204	.559	254	261	147	1661	19	011	.0057	193	20	-	2.77	.05	872
A-746	.	..	-	-	-	..	-	-	-	..	209	.562	255	261	167	1887	24	015	0074	203	27	-	278	.07	876
A 760	-	-	-	..	..	..	..	..	.	-	212				1.83	20.68	27	018	0088	205		-			
A-747	-	-	-	.	..	..	-	.	..	-	-	.558	254	2.61	1.90	21.47		.021	0089	236	3.8	-	277	.10	877
A-748	-	-	.	..	..	.	.	.	.	-	207	.561	255	261	198	2237	22	.020	0103	194	3.6	-	278	.10	8.78
A 759	-	-	.	-	..	..	-	..	..	..	207	.541	246	263	209	2362	22	026	0116	226	48	-	2.68	.13	871
A-749	-	-	.	..		.		.	.	-	203	.551	250	262	230	2599	18	.068	.0140	486	123	-	272	.34	896
A-758	-	..	..	..	.	-	-	..	-	..	203	.552	250	262	232	2621	18	.070	0142	493	127	-	272	.35	897
A-762	..	-	.	-	..	..	..	..	..	..	204	546	248	263	232	2621	19	.072	0142	507	132	-	270	36	896
A-754	..		.	-	-			..	.	..	201	556	253	261	248	2802	16	136	.0162	839	244	.	276	.67	933
A-751	-	.	-	..	..	..	.	-	-	-	200	561	255	261	267	3017	15	.110	0188	585	196	-	278	55	923
A-755	.	-	.	.	.	.	-	.		.	203	.561	255	261	272	3074	18	110	0195	564	196	-	278	.55	923
A-752	-	-	-	.	-	-	.			..	206	561	255	261	276	3119	21	093	0201	462	166	-	278	46	914
A-757		.	.	-	-	.	-	.	..	-	204	551	250	262	287	3243	19	088	0218	404	166		272	44	906
A-756	.	.	.	-	.	.	-		..		206	558	254	261	289	3266	21	061	0220	277	109	-	277	50	897
A-753	.	.	..	..		.	..		..	-	202	564	256	260	3.10	3503	17	026	0253	105	46	-	279	12	881
							Average					555	252	261			23					5.90	275		

SPAN NO. 4

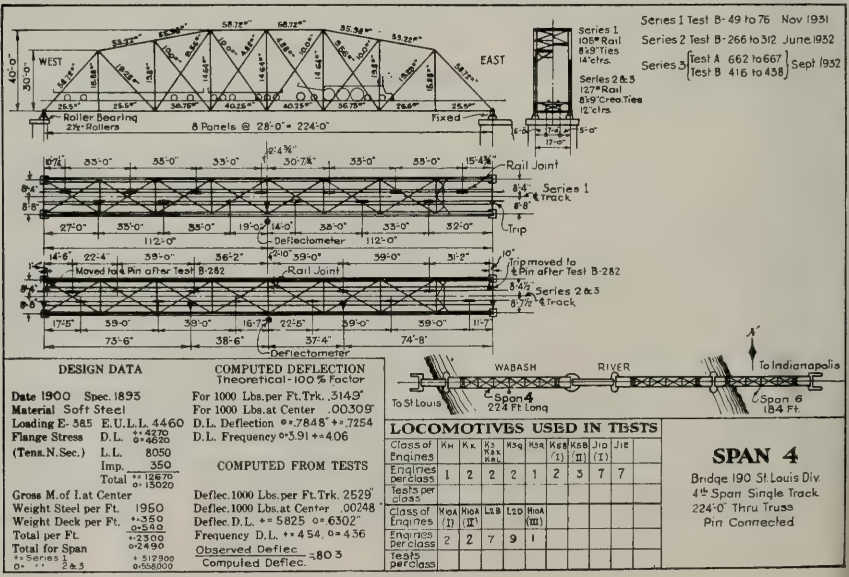
A single track pin connected through truss, 224 ft. long, and 40 ft. deep, center to center of chords. It is of comparatively light design and has small expansion rollers, 2.5 inches in diameter. See Fig. 31.

This span is in the same bridge, as Span No. 6, a 184 ft. truss, and was tested at the same time, so that the test runs are the same on both except as to speed. Tests were made at three different times, the deck being renewed, and heavier rail laid, between Series 1 and 2. At the time the tests of the second series were made, the water was so high and swift, that the deflection readings are not reliable and they have been omitted. The recorded oscillations were less affected and have been included, but it will be found that most of the plotted values, which are low, are of this series.

The structure is located just west of a terminal, and a stop for all passenger trains, so that the westbound trains had practically a full tank of coal and water; this accounts for the greater deflections and lower frequencies for westbound movements. All tests, except those for H10-A, Eng. No. 146, were obtained with regularly scheduled trains.

From the known engine, tender, and car weights, the theoretical deflections were computed for several runs, and when compared with the actual deflection, the deflection factor was found to be .803. The corresponding dead load deflection is, for Series 1, 0.5825 inch, and for Series 2 and 3, 0.6302 inch, giving unloaded frequencies of 4.54 and 4.36. The deflections, D_h, due to the hammer blow at 1 r.p.s. acting statically at the center of the span, were found to be as follows:

Class of Locomotive	D_h (Inches)	*Class of Locomotive*	D_h (Inches)
J1-E	.003910	K-H	.002965
J1-D	.003967	L2-D	.004952
K5-B—Types I and II	.003663	L2-B	.004270
K3-Q	.003840	H10-A—Type I	.002927
K3-R	.003426	" II	.003220
K3-L and K3-K	.003803	" III	.002969
K-K	.002843		



Series 1 Test B-49 to 76 Nov 1931
Series 2 Test B-266 to 312 June 1932
Series 3 {Test A 662 to 667, Test B 416 to 438} Sept 1932

DESIGN DATA

Date 1900 Spec. 1893
Material Soft Steel
Loading E-38.5 E.U.L.L. 4460
Flange Stress D.L. += 4270, o= 4620
(Tens. N. Sec.) L.L. 8050
Imp. 350
Total += 12670, o= 13020
Gross M. of I. at Center
Weight Steel per Ft. 1950
Weight Deck per Ft. += 350, o= 540
Total per Ft. += 2300, o= 2490
Total for Span + 512900, o= 558,000
+= Series 1
o= " 2 & 3

COMPUTED DEFLECTION
Theoretical - 100 % Factor

For 1000 Lbs. per Ft. Trk. .3149"
For 1000 Lbs. at Center .00309"
D.L. Deflection o= .7848" += .7254
D.L. Frequency o= 3.91 += 4.06

COMPUTED FROM TESTS

Deflec. 1000 Lbs. per Ft. Trk. 2529"
Deflec. 1000 Lbs. at Center .00248"
Deflec. D.L. += 5825 o= .6302"
Frequency D.L. += 4.54, o= 4.36

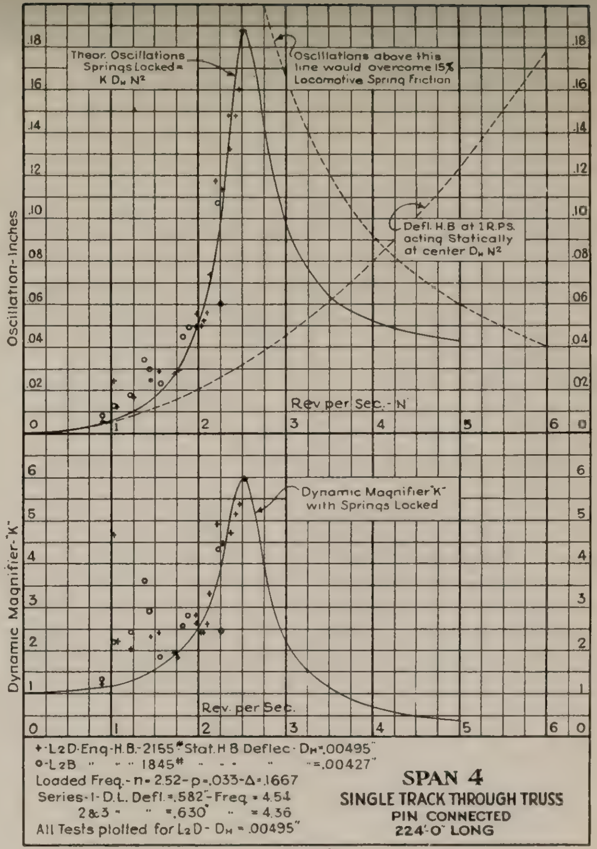
$$\frac{\text{Observed Deflec}}{\text{Computed Deflec.}} = .803$$

LOCOMOTIVES USED IN TESTS

Class of Engines	KH	KK	K3 K3K K3L	K3Q	K3R	K5B (I)	K5B (II)	J1D (I)	J1E	
Engines per class	1	2	2	2	1	2	3	7	7	
Tests per class										
Class of Engines	H10A (I)	H10A (II)	L2B	L2D	H10A (III)					
Engines per class	2	2	7	9	1					
Tests per class										

SPAN 4
Bridge 190 St. Louis Div.
4th Span Single Track
224'-0" Thru Truss
Pin Connected

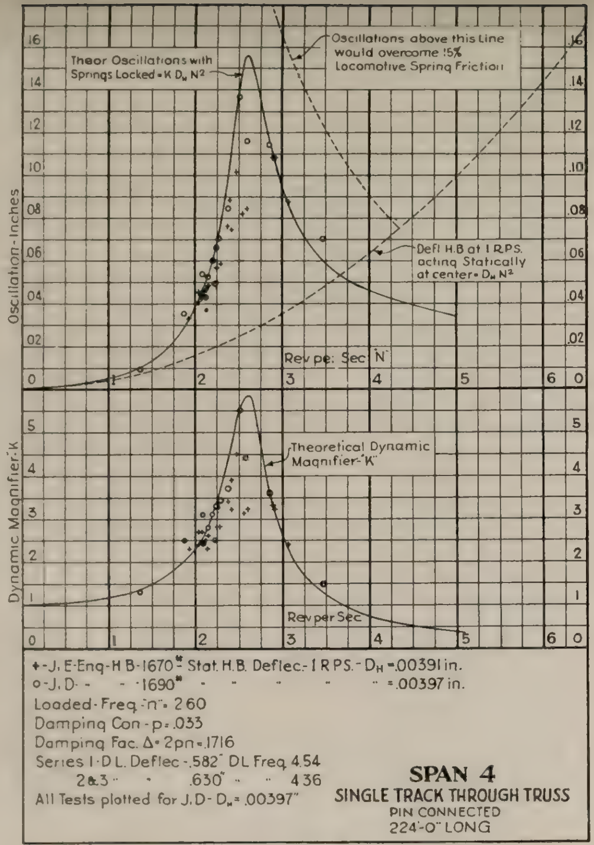
Fig. 31



+ - L$_2$D - Eng - H.B. - 2155# Stat. H B Deflec - D$_H$ = .00495"
o - L$_2$B " " 1845# " " " " = .00427"
Loaded Freq. - n = 2.52 - p = .033 - Δ = .1667
Series - 1 - D.L. Defl. = .582" - Freq. = 4.54
2 & 3 " " = .630" " = 4.36
All Tests plotted for L$_2$D - D$_H$ = .00495"

SPAN 4
SINGLE TRACK THROUGH TRUSS
PIN CONNECTED
224'-0" LONG

Fig. 32



+ - J. E - Eng - H B - 1670# Stat. H.B. Deflec - 1 R PS. - D$_H$ = .00391 in.
o - J. D - " - 1690# " " " " " = .00397 in.
Loaded - Freq. "n" = 2.60
Damping Con - p = .033
Damping Fac. Δ = 2pn = .1716
Series 1 - D L. Deflec - .582" DL Freq. 4.54
2 & 3 " " .630" " " 4.36
All Tests plotted for J. D - D$_H$ = .00397"

SPAN 4
SINGLE TRACK THROUGH TRUSS
PIN CONNECTED
224'-0" LONG

Fig - 33

TABLE-XVIII

BR. 190 ST. LOUIS DIV. 224'-0" SINGLE TRACK-THROUGH TRUSS-PIN CONNECTED

Sheet 1 Span 4

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency 'c'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No.	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H	Dist. "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
B-65	1	S	E	J1E	6620	1670	351.5	255.5	8	P	164.0	1.197	4.73	2.59	1.92	27.15	32.7	.033	.0144	2.3	2.7	4.27	8.77	.21	13.25
B-74	1	"	W	"	6625	"	"	299.9	9	"	164.7	1.257	4.97	2.55	2.03	28.69	33.4	.039	.0161	2.4	3.1	"	9.22	[illegible]	13.77
B-433	3	"	W	"	6625	"	"	299.9	14	"	161.2	1.259	4.98	2.52	2.04	28.82	29.9	.044	.0163	2.7	3.5	4.62	9.24	.32	14.18
B-421	3	"	E	"	6629	"	"	265.9	11	"	158.6	1.180	4.66	2.57	2.07	29.23	27.3	.045	.0167	2.7	3.8	"	8.64	.32	13.58
A-675	3	"	W	"	6620	"	"	299.9	13	"	161.3	1.210	4.78	2.55	2.07	29.22	30.0	.041	.0167	2.4	3.4	"	8.87	.30	13.79
B-271	2	"	W	"	6629	"	"	299.9	11	"					2.13	30.00		.041	.0176	2.3		"			
B-281	2	"	W	"	6628	"	"	299.9	13	"					2.13	30.08		.046	.0176	2.5		"			
B-431	3	"	W	"	6620	"	"	300.4	14	"	166.3	1.269	5.01	2.51	2.14	30.12	35.0	.047	.0179	2.6	3.7	"	9.29	.34	14.25
A-666	3	"	W	"	6629	"	"	300.4	14	"	160.2	1.258	4.97	2.52	2.25	31.66	28.9	.056	.0198	2.8	4.5	"	9.22	.42	14.26
B-423	3	"	E	"	6620	"	"	262.4	12	"	160.0	1.189	4.70	2.56	2.27	31.97	28.7	.057	.0201	2.8	4.9	"	8.72	.43	13.77
B-56	1	"	W	"	6623	"	"	299.9	10	"	162.0	1.242	4.91	2.56	2.38	33.60	30.7	.075	.0221	3.4	6.0	4.27	9.11	.56	13.93
B-71	1	"	E	"	6629	"	"	262.4	11	"	159.0	1.195	4.72	2.59	2.40	33.85	27.7	.087	.0225	3.9	7.3	"	8.76	.64	13.67
A-672	3	"	W	"	6625	"	"	299.9	12	"	160.2	1.258	4.97	2.52	2.41	33.92	28.9	.073	.0227	3.2	5.8	4.62	9.22	.54	14.38
B-69	1	"	W	"	6620	"	"	299.9	10	"	166.7	1.314	5.20	2.52	2.47	34.85	35.4	.108	.0238	4.5	8.1	4.27	9.65	.78	14.70
B-273	2	"	E	"	6625	"	"	259.0	-	"					2.55	35.93		.080	.0254	3.1		4.62			
B-432	3	"	E	"	6621	"	"	265.9	11	"	157.0	1.204	4.75	2.55	2.59	36.49	25.7	.083	.0262	3.2	7.0	"	8.81	.62	14.05
B-59	1	"	E	"	6622	"	"	262.4	11	"	159.7	1.197	4.73	2.59	2.89	40.77	28.4	.106	.0326	3.3	8.9	4.27	8.77	.78	13.82
B-269	2	"	E	"	6628	"	"	265.9	13	"					2.90	40.90		.106	.0330	3.2		4.62			
B-665	3	"	E	"	6628	"	"	265.9	11	"	160.5	1.220	4.82	2.54	3.06	43.08	29.2	.086	.0366	2.4	7.3	"	8.94	.65	14.21
				Average W. Bound			351.5	300.0			162.8	1.258	4.97	2.53			31.5					4.50	9.23		
				Average E. Bound			351.5	262.9			159.8	1.197	4.73	2.57			28.5					4.50	8.77		

Sheet 2 Span 4

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R P S "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-676	3	S	E	J1D	6609	1690	353.0	262.3	11	P	157.8	1.203	4.75	2.56	1.36	19.10	26.3	.019	.0066	0.3	1.6	4.62	8.81	.14	13.57
B-302	2	"	E	"	6610	"	"	262.3	13	"					1.88	26.44		.035	.0140	2.5		"			
B-422	3	"	W	"	6613	"	"	300.4	12	"	164.7	1.239	4.90	2.53	2.08	29.29	33.2	.054	.0172	3.1	4.4	"	9.09	.39	14.10
B-278	2	"	W	"	6607	"	"	301.0	12	"					2.11	29.71		.043	.0177	2.4		"			
B-418	3	"	W	"	6607	"	"	301.0	12	"	166.3	1.241	4.90	2.53	2.14	30.19	34.8	.052	.0182	2.8	4.2	"	9.09	.38	14.09
B-287	2	"	W	"	6608	"	"	301.0	13	"					2.20	31.02		.060	.0192	3.1		"			
B-312	2	"	W	"	6610	"	"	301.0	11	"					2.23	31.45		.049	.0197	2.5		"			
A-663	3	"	W	"	6609	"	"	301.0	13	"	161.8	1.291	5.10	2.50	2.24	31.51	30.3	.066	.0199	3.3	5.1	"	9.46	.49	14.57
B-283	2	"	W	"	6600	"	"	292.0	7	"					2.27	32.05		.070	.0204	3.4		"			
A-668	3	"	E	"	6607	"	"	262.3	11	"	158.5	1.184	4.68	2.57	2.38	33.55	27.0	.084	.0225	3.7	7.1	"	8.68	.62	13.92
A-673	3	"	E	"	6611	"	"	266.4	11	"	158.0	1.216	4.81	2.55	2.51	35.36	26.5	.137	.0249	5.5	11.2	"	8.92	1.00	14.54
B-289	2	"	E	"	6607	"	"	262.9	13	"					2.58	36.40		.116	.0264	4.4		"			
B-435	3	"	E	"	6607	"	"	266.4	11	"	156.0	1.210	4.78	2.55	2.85	42.14	24.5	.114	.0322	3.6	9.4	"	8.87	.83	14.32
B-311	2	"	E	"	6211	"	"	262.3	-	"					3.48	49.00		.070	.0481	1.5					
				Average W Bound			353.0	301.0			164.3	1.257	4.97	2.52			32.8					4.62	9.31		
				" E Bound			353.0	263.7			157.6	1.206	4.76	2.56			26.1						8.82		

Sheet 3 Span 4

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L : Defl		E U L L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Tender	No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)				DL	LL	Imp	Total
B-274	2	S	W	K5B I	6507	1560	2975	2473	8	P					209	2954		052	0160	33		462			
A-677	3	"	W	"	6510	"	"	262.9	7	"	1645	1154	456	259	226	3182	332	076	0187	41	66	"	8.46	56	1364
A-667	3	"	W	"	6508	"	"	2231	8	"	1592	1073	424	265	231	3252	280	088	0195	45	82	"	787	.65	1314
B-76	1	·	E	· II	6518	"	3020	238.2	7	"	1620	1125	444	265	232	3272	307	093	0197	47	83	427	824	68	13.19
A-436	3	"	W	"	6517	·	"	2629	7	"	1620	1179	466	257	233	3280	30.7	.091	0199	46	77	4.62	864	67	1393
B-64	1	"	E	" I	6508	·	2975	238.2	7	"	1608	1.112	440	266	239	3375	29.5	.089	0209	43	8.0	427	816	.65	1308
B-424	3	"	W	"	6508	·	"	2629	7	"	1612	1149	454	259	240	3389	299	.088	0211	42	77	462	842	65	1369
B-52	1	"	E	·	6507	"	"	2382	–	"	1616	979	387	273	289	4074	303	.032	0306	10	32	427	718	23	1168
	Type I Average W Bound						2975	251.8			1618	1125	444	261			30.5					462	825		
	Type I - Average E Bound						2975	2382			1612	1046	413	269			299					427	767		
	Type II - Average W Bound						3020	251.8			162.0	1179	466	257			307					462	864		
	Type II Average E Bound						302.0	238.2			1620	1125	444	265			307					427	824		
B-304	2	S	W	K3Q	6486	1645	2955	2004	7	P					212	2992		028	0172	16		462			
B-66	1	"	W	"	6485	"	·	1996	7	"	1572	1069	423	269	243	3426	266	.064	0226	29	6.0	427	785	.47	1259
A-669	3	S	W	K3R	6500	1465	278.0	1988	7	P	1632	1062	420	266	242	3413	323	038	0201	1.9	3.6	462	779	28	1269
A-75	1	S	W	K3L	6473	1605	2740	1914	7	P	1580	1009	399	275	222	3136	27.4	.037	.0187	20	36	427	740	.26	1193
B-63	1	"	W	K3K	6465	"	"	1904	7	"	1510	1009	399	275	234	3304	204	.036	.0208	17	35	427	740	26	1193
B-57	1	S	W	K-K	6442	1210	242.0	159.2	4	P	1610	896	354	285	276	3697	414	041	.0216	19	46	427	657	30	1114
B-73	1	"	E	"	6444	"	"	966	3	"	1540	.824	326	292	278	3727	344	035	0220	16	42	427	6.05	25	1057
B-61	1	S	E	K-H	6425	1260	2360	1050	3	P	1500	830	3.28	2.91	206	2764	304	.035	.0126	29	42	427	6.08	.25	1060

Sheet 4 Span 4

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L : Defl		E U L L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Tender	No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)				DL	LL	Imp	Total
B-55	1	S	E	L2D	6241	2155	3670	2342	-	F	1647	1088	427	268	.90	1108	305	005	0041	1.2	04	427	792	.03	1222
A-674	3		E	"	6246	·	·	2275	61	"	1594	1175	464	258	1,02	1250	252	024	0051	47	20	462	861	17	1340
B-419	3	·	E	"	6241	·	"	229.6	79	·	1553	1087	430	264	106	1304	211	.012	0055	2.2	11	"	798	09	1269
B-434	3	·	E	"	6246	·	"	2707	73	"	1530	1183	467	257	123	1516	188	015	.0075	20	13	"	866	.11	1339
B-68	1	"	E	"	6246	"	"	2394	–	"	1628	1199	474	259	145	1785	286	.024	0104	23	22	427	879	.19	1325
B-67	1		W	"	6248	·	·	3048	–	·	1536	1184	468	261	1.54	1896	194	028	0117	24	24	·	868	21	1316
B-70	1		W	L2D	6246	·	·	3048	–	-					164	20.13		.034							
(DH)				H10A1	25	1270	3350	2713		-		1615			179	2013		.035							
B-60	1		E	L2D	6240	2155	3670	2294	64	·	15.2	1083	428	268	171	2098	170	.027	.0145	19	3.6	·	794	28	1249
B-272	2		W	·	6243	·	·	2907	–						176	2170		028	.0153	18		462			
B-426	3		W	·	6240	·	"	3048	74	·	1606	1199	474	256	1.97	2421	264	.055	0192	28	47	"	879	41	1382
B-284	2		E	·	6244	·	·	2342	65	-					198	2430		.049	.0194	26		·			
A-662	3		W	"	6240	·	·	3048	57	·	158.0	1244	492	253	202	2491	238	049	0202	24	40	"	913	36	1411
B-425	3		E	"	6245	·	·	2551	50		1523	1148	454	260	204	2508	181	.051	0206	24	44	"	842	37	1341
B-308	2		E	·	6247	·	·	2284	44						2.10	2581		056	0218	26		·			
B-430	3		W	·	6245	·	"	3048	66		1597	1260	500	252	212	2606	25.5	074	.0222	33	5.8	"	978	54	1444
A-678	3		E	"	6240	·	"	2342	55	-	1570	1170	462	258	219	2678	228	.117	0238	49	100	"	857	86	14.05
B-276	2		W	"	6246	·	"	3048	47		1657	1203	475	256	226	2774	315	.113	.0253	44	94	-	881	.83	1426
B-416	3		W	"	6246	·	"	3048	49		1638	1291	510	2.52	238	2923	296	132	.0280	471	102	"	946	96	15.04
B-310	2		E	·	6240	·	·	2304	51						243	2989		148	0292	51		·			
B 438	3		E	"	6242	·	·	2521	65		1550	1199	4.74	256	246	3031	208	.160	0299	555	133	"	879	117	1458
B 429	3		W	"	6241	"	"	2544	46	·	1682	1278	505	251	252	3097	340	188	0314	595	147	-	937	138	1537
			Average W		Bound		3670	2976			1614	1237	489	254			272					457	907		
				" E	"		3670	2414			1567	1148	454	261			225					450	841		

Sheet 5 Span 4

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow D N² at Center	Dynamic Magnifier k	Impact	Moment Unit Stress (Kips) Tens Net Sec			
No.	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Tender	No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)				D L	L L	Imp	Total
B-291	2	S	E	L2 B	6203	1845	3640	2107	101	F					90	1112		.008	0035	23		462			
B-72	1	"	E	"	6201	"	"	211.9	60	"	153.7	1057	418	272	104	1274	196	.010	.0046	2.2	0.9	427	775	.07	12 09
A-679	3	"	W	"	6204	"	"	2818	83	"	1570	1153	456	259	1.23	15.09	22.9	.015	.0064	24	13	462	8.46	.11	13.19
B-279	2	"	E	"	6207	"	"	2115	81	"					138	16.93		.029	.0081	3.6		"			
B-427	3	"	E	"	6202	"	"	2629	-	"	1540	1102	436	263	1.44	1766	199	.025	0088	29	2.3	"	809	.18	12 89
B-58	1	"	W	"	6200	"	"	287.0	53	"	1631	1.174	4.64	261	1.56	1914	290	019	.0104	18	1.6	427	861	14	13 02
B-270	2	"	E	"	6203	"	"	206.4	-	"					1.83	2247		.038	0143	26		462			
B-437	3	"	W	"	6202	"	"	281.8	99	"	162,0	1229	486	254	188	23.08	27.9	042	.0150	2.8	3.4	"	9.02	30	13 94
B-305	2	"	E	"	6202	"	"	212.6	69	"					222	2726		.092	.0211	4.3		-			
A-670	3	"	W	"	6206	"	"	287.0	64	"	1569	1200	474	256	226	2786	22.8	.052	0218	24	4.3	"	879	.21	13 62
				Average	W Bound		3640				1597	1153	456	257			256					453	872		
				"	E "		3640				1538	1080	4.27	2.67			197					456	792		
B-294	2	S	W	H10A II	146	1390	335.0		6	F					.97	1091		.010	0030	33		462			
A-671	3	"	E	"	169	"	"	2281	77	"		1.189	4.70	264	L28	144		.014	0053	27	1.2	"	872	.10	13 44
B-70	1	"	W	L2D	6246	2155	3670	304.8	-	"					164	20.13		.034				427			
(DH)		"		H10A I	25	1270	335.0	2713		"		1.615			179	2013		.035				"			
B-300	2	"	W	H10A II	146	1390	"		6	"					180	20.26		.028	0104	2.7		462			
B-54	1	"	W	" I	5	1270	"	241.3	-	"	153.5	1.067	422	271	1.89	2125	238	030	.0105	29	2.8	427	783	.22	12 32
B-420	3	"	W	" II	169	1390	"	273.4	62	"					207	2321		.091				462			
DH		"		G46H	6866	2080	246.0	1490		-		1434			228	2321		157				.			
B-417	3	"	E	H10A III	174	1280	335.0	219.7	101	"	1492	1098	4.34	2.65	211	2377	18.9	052	.0132	40	47	"	805	.35	13 02
B-298	2	"	W	" II	146	1390	"		6	"					214	2401		.059	0147	33		"			
B-428	3	"	E	" III	150	1280	"	231.5	67	"	1500	1171	463	261	215	24 21	197	.097							

Sheet 6 Span 4

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L L Defl.		E U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow D N² at Center	Dynamic Magnifier 'k'	Impact	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Tender	No	Kind	at Dist "P"	Defl. (ins) "D"			R.P.S. "N"	M.P.H	Dist "H" (Ft.)	Oscil (ins)				D.L.	L.L.	Imp.	Total
B-297	2	S	W	H10A II	146	1390	335.0		6	F					255	2865	37.5	.080	.0209	3.8		462			
B-295	2	"	W	-	146	1390	335.0		6	F					259	2916	346	.071	.0216	3.3		"			
B-296	2	-	W	"	146	1390	3350		6	F					2.81	31 57	34.1	.038	.0254	15		"			
B-299	2	-	W	"	146	1390	335.0		6	F					3.01	3387	29.8	.039	.0292	1.3		"			

NOTE - On account of heavy current and drift during tests of Series 2 Crowl deflection readings are not reliable and have been omitted.

Readings of oscillations have in most cases been shown.

Deck was renewed and heavier rail was laid after tests of Series 1.

Test B-429, for an L2-B locomotive running at 2.52 r.p.s., which happened to be synchronous speed, has an oscillation of .188 inch. The damping factor Δ, from this test was found to be 0.167, which gives for p, the damping constant, a value of .033. Using this value, the theoretical and actual oscillations and dynamic magnifiers for the L2-B and L2-D locomotives are shown in Fig. 32, the measured oscillations for the L2-B engines being multiplied by the factor, 1.16, so that they will be comparable to those of the L2-D.

The loaded frequency for the westbound J1-D and J1-E engines is 2.52, and the corresponding Δ, is $2pn = .066 \times 2.52 = .1716$. Using this value, a comparison of the theoretical and measured values of oscillations and dynamic magnifiers for these two classes is shown in Fig. 33.

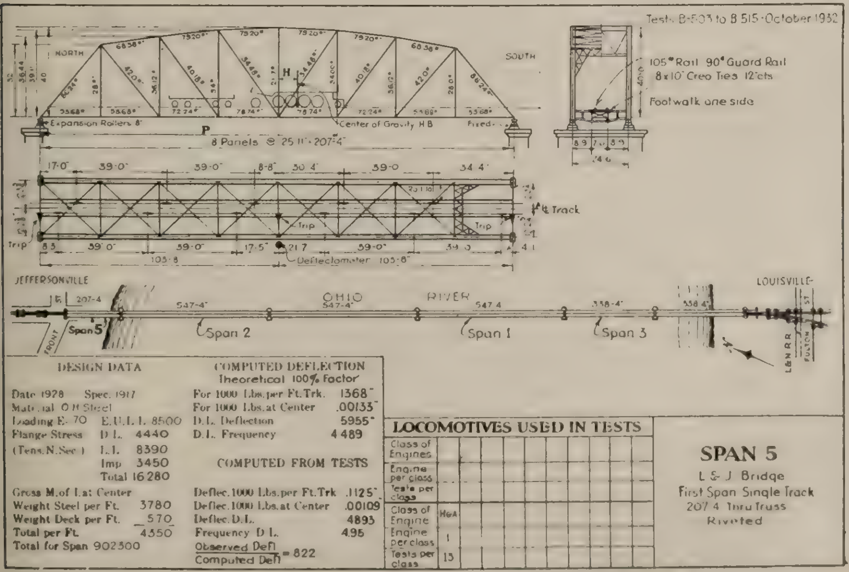
This span is not deep, and we might have expected to find the damping constant to be about .022 to .025, but such a value cannot be obtained from any of the tests. The higher value of .033 is undoubtedly due to a comparatively large amount of end bearing friction, as the rollers were small and not in the best condition.

We again find that the oscillations are neither rapid enough nor of such magnitude, as to overcome the friction of the locomotive springs, so they remain locked, or inactive.

SPAN NO. 5

A single track riveted through truss span, 207 feet, 4 inches long, and 40 feet deep, and weighing 902,300 lb. See Fig. 34.

This span was adjacent to Span No. 2, and tested by the same H6-A locomotive. From the average measured deflection of .424 inch, the deflection factor was found to be .822, and the dead load deflection .4893 inch. The deflection, due to the hammer blow of 2140 lb. acting statically, is .00216 inch; the unloaded and loaded frequencies being 4.95 and 3.63.



DESIGN DATA

Date 1928 Spec. 1917
Material O H Steel
Loading E-70 E.U.L.L. 8500
Flange Stress D.L. 4440
(Tens. N. Sec.) L.L. 8390
Imp 3450
Total 16280
Gross M. of I. at Center
Weight Steel per Ft. 3780
Weight Deck per Ft. 570
Total per Ft. 4350
Total for Span 902300

COMPUTED DEFLECTION
Theoretical 100% Factor

For 1000 Lbs. per Ft. Trk. .1368"
For 1000 Lbs. at Center .00133"
D.L. Deflection .5955"
D.L. Frequency 4.489

COMPUTED FROM TESTS

Deflec. 1000 Lbs. per Ft. Trk .1125"
Deflec. 1000 Lbs. at Center .00109"
Deflec. D.L. .4893
Frequency D.L. 4.95
$\frac{\text{Observed Defl}}{\text{Computed Defl}} = .822$

LOCOMOTIVES USED IN TESTS

Class of Engines										
Engine per class										
Tests per class										
Class of Engine	H6A									
Engine per class	1									
Tests per class	13									

SPAN 5
L & J Bridge
First Span Single Track
207 4 Thru Truss
Riveted

Fig. 34

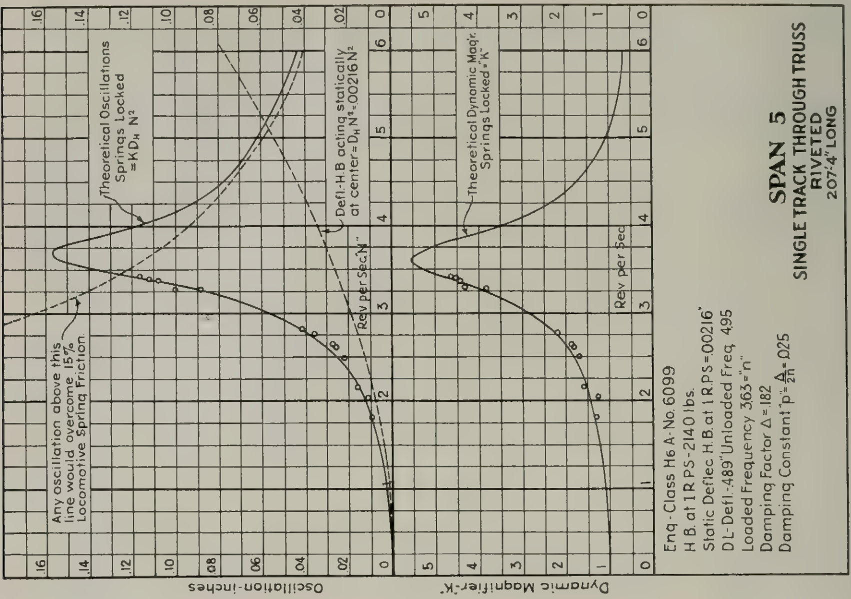


Fig.-35

TABLE XIX

LOUISVILLE BRIDGE-207'-4" SINGLE TRACK RIVETED THRU TRUSS SPAN-CARBON STEEL Sheet 1 Span 5

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1 RPS	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist "P"	Stat L L Defl Defl (ins) D	E.U.L.L (Kips)	Loaded Frequency "n"	Speed R.P.S "N"	Speed M P H	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
B-503	I	W	N	H6A	6099	2140	2908	1856	None		144.0	.428	3.81	3.62	1.80	20.26	24.6	.009	.0070	1.29	2.1	4.44	3.89	.08	8.41
B-504	"	"	"	"	"	"	"	"	"	"	140.7				2.03	22.76	21.3	.011	.0089	1.24		"			
B-505	"	"	"	"	"	"	"	"	"	"	141.0	.424	3.77	3.63	2.16	24.31	21.6	.016	.0101	1.58	3.8	"	3.85	.14	8.43
B-509	"	"	"	"	"	"	"	"	"	"	142.5	.420	3.73	3.64	2.49	28.01	23.1	.022	.0134	1.64	5.2	"	3.80	.20	8.44
B-506	"	"	"	"	"	"	"	"	"	"	141.0	.428	3.81	3.62	2.60	29.22	21.6	.026	.0146	1.78	6.1	"	3.89	.23	8.56
B-507	"	"	"	"	"	"	"	"	"	"	144.0	.427	3.80	3.62	2.62	29.41	24.6	.027	.0148	1.83	6.3	"	3.88	.24	8.56
B-514	"	"	"	"	"	"	"	"	"	"	135.6	.427	3.80	3.62	2.76	30.90	16.2	.036	.0164	2.19	8.7	"	3.88	.33	8.65
B-508	"	"	"	"	"	"	"	"	"	"	135.4	.422	3.75	3.63	2.81	31.60	16.0	.041	.0171	2.40	9.7	"	3.82	.37	8.63
B-515	"	"	"	"	"	"	"	"	"	"	135.3	.420	3.73	3.64	3.27	36.76	15.9	.089	.0231	3.85	21.2	"	3.80	.81	9.05
B-510	"	"	"	"	"	"	"	"	"	"	134.0	.428	3.81	3.62	3.28	36.87	14.6	.100	.0232	4.31	23.4	"	3.89	.91	9.24
B-511	"	"	"	"	"	"	"	"	"	"	133.8	.424	3.77	3.63	3.36	37.97	14.4	.108	.0244	4.42	25.5	"	3.85	.98	9.27
B-513	"	"	"	"	"	"	"	"	"	"	136.0	.420	3.73	3.64	3.39	38.31	16.6	.112	.0250	4.48	26.7	"	3.80	1.02	9.26
B-512	"	"	"	"	"	"	"	"	"	"	134.7	.422	3.75	3.63	3.41	38.53	15.3	.116	.0251	4.62	27.5	"	3.82	1.05	9.31
							Average				138.3	.424	3.77	3.63			18.9					4.44	3.84		

Owing to the heavy grades on the approach it was impossible to attain high speed, but several runs were near enough to synchronism to arrive at a value of the damping factor Δ, which, from tests B-510, 511 and 512, was found to be .182, giving a value for the damping constant, p, of .025. In Fig. 35, are shown the calculated and actual oscillations and dynamic magnifiers, and the agreement is close throughout the entire range of speeds.

Assuming 15 per cent locomotive spring friction we might expect spring damping to come into play at about 3.45 r.p.s., at which time the oscillation would have been .124 inch but unfortunately the fastest test run was 3.41 r.p.s. However, the test load was quite light, and had this span been loaded to capacity, its frequency would have been in the neighborhood of 2.50, and the oscillations at that frequency could scarcely be of such size as to overcome spring friction, but on spans somewhat shorter than this we find this action taking place.

SPAN NO. 6

A single track pin connected through truss, 184 ft. long, 30 ft., 8 inches deep, center to center of chords. See Fig. 36.

This span was tested in conjunction with Span No. 4, so that the test runs correspond except as to speed, the westbound trains having the heavier tender loading. Tests were run at three different times, and like Span No. 4, the deck was renewed and heavier rail laid between the tests of Series 1 and 2.

From the known engine, tender and car weights, the following deflection factors were found:

Test train—H10-A—Locomotive 146	.834
J1-E Locomotives—Average—Westbound	.849
J1-D " — " — "	.846
J1-D " — " —Eastbound	.840

An average value of .842 was used, giving a dead load deflection of 0.4716 inch for tests of Series 1, and 0.5049 inch for tests of Series 2 and 3, the corresponding frequencies of the unloaded span being 5.04 and 4.88. The calculated hammer blow deflections D for the various classes of locomotives, are:

Class of Locomotive	D_h (Inches)	*Class of Locomotive*	D_h (Inches)
J1-E	.003000	K-H	.002654
J1-D	.003056	L2-D	.003806
K5-B—Types I and II	.002804	L2-B	.003257
K3-Q	.002954	H10-A—Type I	.002264
K3-R	.002901	" II	.002473
K3-K, K3-L	.002880	" III	.002273
K-K	.002182		

From Test A-543, a J1-E Engine running at 2.95 r.p.s., and assuming an average frequency of 2.87, Δ was found to be 0.1768, giving a value for the damping constant, p, of .0308. Other tests gave slightly higher values. Using this value of Δ, the theoretical dynamic magnifiers, k, and the oscillations, based on the D_h for the J1-D locomotives, have been computed and are shown in Fig. 37. The measured oscillations for the J1-D and J1-E engines, are also shown and they agree very well.

In Fig. 38, the same information is given for the L2-B, L2-D, and H10-A locomotives, using the same value of *p*. An average frequency, *n*, of 2.85 was selected, so that the new, Δ becomes .1786. The hammer blow deflection, D_h, for the L2-D class, was used, which necessitated multiplying the measured oscillations of the other classes of locomotives by the following factors:

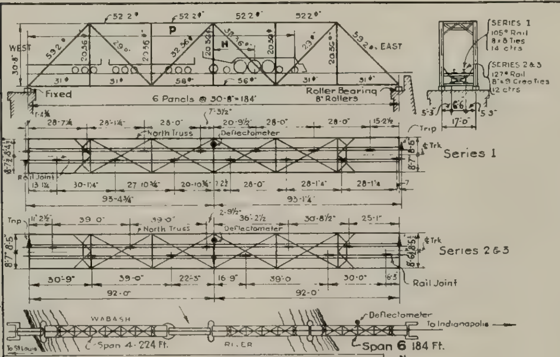
L2-B, 1.17; H10-A—Type I, 1.695; Type II, 1.54; and Type III, 1.67. When this is done, it will be seeen that the actual values are very close to the theoretical.

For some reason this span is particularly susceptible to vibration when the engines are running at one-half the synchronous speed, and this is particularly noticeable with freight locomotives as shown in Fig. 38. This effect is clearly shown on the records, the somewhat smaller free oscillations occurring midway between the forced oscillations.

The circumference of the drivers of the locomotives used in the tests on this span varied from 16.5 ft. for the H10-A Class, to 20.7 for the J1-E Class, a difference of 25 per cent, but the effect on the dynamic magnifier is not apparent. The same thing has been found on other of the longer spans tested, which fact would seem to justify the use of formulas based on the stationary oscillator theory rather than that based on the moving pulsating force.

The value of .0308 for the damping constant, *p*, is not far out of line, although it is somewhat high, probably due to excess end friction. This span is 30 years old, the expansion rollers were badly corroded and the bearing plates corrugated; in fact they were in such condition that they have since been repaired.

In this span we again find the oscillations of such a character that they are incapable of overcoming locomotive spring friction, but under the loading used they are approaching that condition. With capacity loading their frequency would be so low that even with a large increase in magnitude, the force, due to acceleration, would still be less than the spring friction.



Series 1 Test A 306 to 333 Nov 1931
" 2 " A 528 to 576 June 1932
Series 3 - A 680 to 638 Sept 1932
Series 3 - B 398 to 415 Sept 1932

DESIGN DATA

Date 1904 Spec. 1901
Material O H Steel
Loading E- 51.6 E.U.L.L. 6240
Flange Stress D.L. +- 3310, 0- 3540
(Tens. N. Sec.) L.L. 7670
Imp. 400
Total +- 11380, 0- 11610
Gross M. of I at Center 2330
Weight Steel per Ft. +- 355
Weight Deck per Ft. 0 - 545
Total per Ft. + - 2685, 0 - 2875
Total for Span + - 495600, 0 - 519,700
+ - Series 1
0 - Series 2 and 3

COMPUTED DEFLECTION
Theoretical 100% Factor

For 1000 Lbs. per Ft. Trk. .2086"
For 1000 Lbs. at Center .00225"
D.L. Deflection + .5600, 0 .5996
D.L. Frequency + 4.63, 0 4.47

COMPUTED FROM TESTS

Deflec. 1000 Lbs. per Ft. Trk. .1756"
Deflec. 1000 Lbs. at Center .00189"
Deflec. D.L. + .4716, 0 .5049
Frequency D.L. + 5.04, 0 4.88

$$\frac{\text{Observed Deflec}}{\text{Computed Deflec.}} = .842$$

LOCOMOTIVES USED IN TESTS

Class of Engines	K-H	K-K	K3J K3K K3L	K3Q	K3R	K5B (I)	K5B (II)	J1D (I)	J1E	
Engines per class	2	2	2	2	1	3	3	7	9	
Tests per Class	2	2	2	3	1	7	3	14	22	
Class of Engines	G6N	H10 A (I)	H10 A (II)	L2B	L2D	H10 A (III)				
Engines per Class	1	2	2	7	7	3				
Tests per Class	1	2	13	11	24	3				

SPAN 6

Bridge 190 St Louis Div
1st Span Single Main
184'-0" Thru Truss
Pin connected

Fig. 36

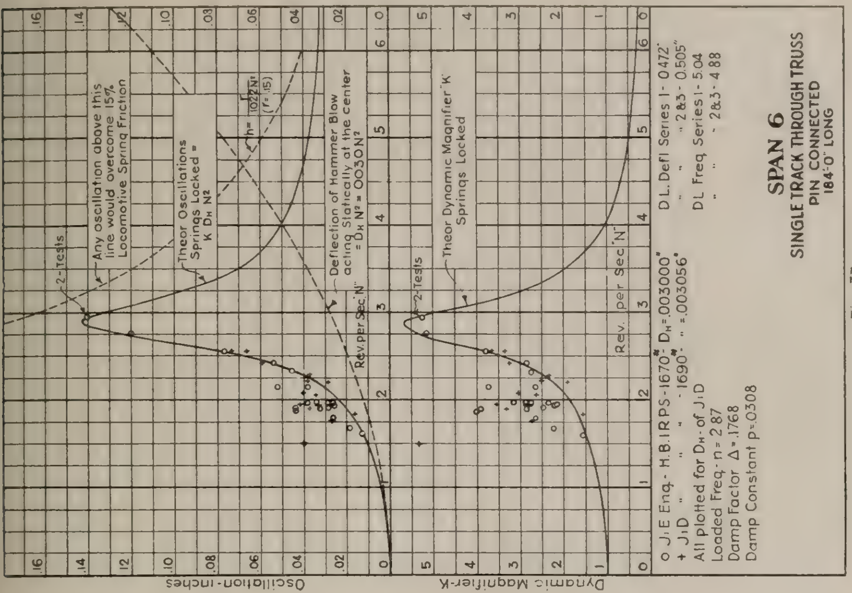

Oscillation - inches
.16
.14
.12
.10
.08
.06
.04
.02
0
Dynamic Magnifier-K
5
4
3
2
1
0
1
2
3
4
5
6
2-Tests
Any oscillation above this line would overcome 15% Locomotive Spring Friction
Theor Oscillations Springs Locked = K D_H N²
h = 1/1022N² (r = .15)
Deflection of Hammer Blow acting Statically at the center = D_H N² = .0030 N²
Rev. per Sec 'N'
2-Tests
Theor Dynamic Magnifier 'K' Springs Locked
Rev. per Sec 'N'
o J.E Eng. - H.B.I R P S - 1670* D_H = .003000"
+ J.D " " " - 1690* " = .003056"
All plotted for D_H - of J.D
Loaded Freq. n = 2.87
Damp Factor Δ = .1768
Damp Constant p = .0308
D.L. Defl Series 1 - 0.472"
" " " 2&3 - 0.505"
DL Freq Series 1 - 5.04
" " " 2&3 - 4.88
SPAN 6
SINGLE TRACK THROUGH TRUSS
PIN CONNECTED
184'-0" LONG

Fig. 37

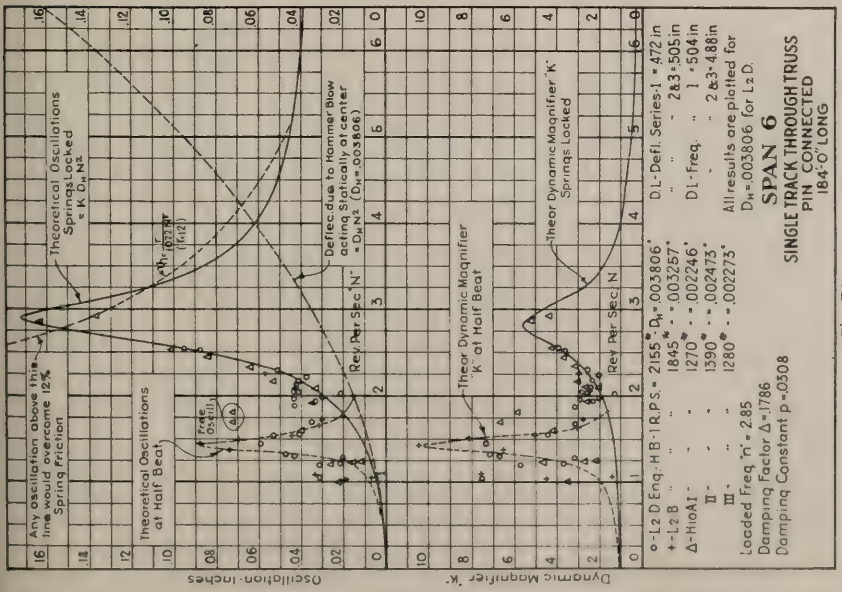

Oscillation - inches
.16
.14
.12
.10
.08
.06
.04
.02
0
Dynamic Magnifier 'K'
10
8
6
4
2
0
1
2
3
4
5
6
Any oscillation above this line would overcome 12% Spring Friction
Theoretical Oscillations at Half Beat
Free Oscill.
Theoretical Oscillations Springs Locked = K D_H N²
h = 1/1022N² (r = .12)
Deflec. due to Hammer Blow acting Statically at center = D_H N² (D_H = .003806)
Rev Per Sec 'N'
Theor Dynamic Magnifier "K" at Half Beat
Theor Dynamic Magnifier 'K' Springs Locked
Rev Per Sec N
o - L2 D Eng. - H B - 1 R.P.S. = 2155* D_H = .003806"
+ - L2 B " " 1845* - = .003257"
Δ - H10 A I - " 1270* - = .002246"
II - " 1390* - = .002473"
III - " 1280* - = .002273"
Loaded Freq 'n' = 2.85
Damping Factor Δ = .1786
Damping Constant p = .0308
D.L. Defl. Series 1 = .472 in
" " " 2&3 = .505 in
D.L. Freq. " 1 = .504 in
" " 2&3 = 4.88 in
All results are plotted for D_H = .003806 for L2 D.
SPAN 6
SINGLE TRACK THROUGH TRUSS
PIN CONNECTED
184'-0" LONG

Fig. 38

TABLE XX

Br-190 ST. LOUIS DIV · 184 Ft SINGLE TRACK - PIN CONNECTED THROUGH TRUSS SPAN Sheet 1 Span 6

Test No.	Test Series	Girder	Direc. of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L.L. Defl at Dist "P"	Stat L.L. Defl Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	Speed R.P.S. "N"	Speed M.P.H	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat. Defl H Blow $D_N N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A-537	2	N	W	J, E	6621	1670	351.5	2999	9	P	1408	.923	526	291	1.60	2259	295	.012	.0077	156	13	354	647	08	10.09
A 570	2	"	W	"	6627	"	"	3004	–	"	1363	1016	579	281	168	2371	250	.019	.0085	223	19	"	7.12	.14	1080
A-549	2	"	W	"	6625	"	"	299.9	7	"	1390	1000	569	2.82	178	2514	277	.025	.0095	263	2.5	"	700	.18	1072
A-331	1	"	W	"	6625	"	"	299.9	9	"	139.7	.964	5.49	289	187	2640	284	.042	.0105	40	43	3.31	675	29	1035
A-307	1	"	E	"	6621	"	"	265.3	–	"	137.4	.948	5.40	291	189	2673	261	.042	.0107	393	44	"	664	29	10.24
B-402	3	"	W	"	6629	"	"	300.4	14	"	1385	969	5.52	285	190	2675	27.0	.031	0108	287	3.2	354	6.79	22	1055
B-411	3	"	W	"	6620	"	"	2999	13	"	1373	.970	552	285	1.91	2699	260	027	0110	245	28	"	6.79	19	1052
A-574	2	"	W	"	6626	"	"	299.9	12	"	139.2	1016	5.79	281	194	2728	279	025	0113	221	24	"	7.12	17	10.83
A-684	3	"	E	"	6629	"	"	265.9	11	"	1300	.936	5.33	2.89	195	2743	187	025	0114	219	27	"	6.56	.18	1028
A-693	3	"	W	"	6620	"	"	300.4	14	"	138.2	.967	552	285	196	2762	269	.027	.0115	235	28	"	6.79	19	10.52
A-695	3	"	W	"	6625	"	"	2999	14	"	133.0	.941	5.36	288	197	27.81	217	033	.0116	284	34	"	6.59	.22	10.35
A-544	2	"	W	"	6628	"	"	2999	13	"	136.0	.987	562	284	197	28.08	24.7	032	.0116	276	32	"	6.91	.22	1067
A-320	1	"	E	"	6620	"	"	255.5	8	"	138.0	.964	5.49	289	1.99	28.45	26.7	.038	.0119	3.18	39	331	675	.27	1033
A-324	1	"	W	"	6620	"	"	2999	10	"	142.0	1002	569	2.85	2.15	30.28	307	.037	.0139	266	37	"	7.00	26	1057
A-311	1	"	W	"	6623	"	"	2999	10	"	139.5	.992	5.65	283	215	3035	282	052	.0139	373	5.2	"	695	.36	10.62
B-408	3	"	W	"	6625	"	"	2999	12	"	137.8	.982	5.59	284	232	3275	265	044	0161	273	45	3.54	6.88	.31	1073
A-327	1	"	E	"	6629	"	"	262.4	11	"	136.5	.974	5.55	2.88	2.43	34.24	252	.051	.0177	288	5.2	331	6.83	.36	10.50
A-694	3	"	E	"	6621	"	"	265.9	11	"	1347	.918	5.23	291	255	35.95	23.4	.075	.0199	377	8.2	3.54	643	53	1050
A-535	2	"	E	"	6625	"	"	259.0	–	"		948	540	288								"	6.64		
A-314	1	"	E	"	6622	"	"	2624	11	"	1349	970	5.52	2.88	277	3913	23.6	118	0230	513	122	331	679	.83	10.93
A-543	2	"	E	"	6629	"	"	265.9	12	"	136.3	.975	5.55	286	295	41.52	250	137	0261	525	14.2	3.54	6.83	.97	11.34
B-401	3	"	E	"	6628	"	"	2659	11	"	1324	.931	5.30	2.87	295	4162	211	137	0261	525	147	"	652	.96	1102
	Average			E. Bound		1670	351.5	263.1			1359	.952	5.42	289			24.6					349	667		
	Average			W Bound		1670	351.5	3000			138.3	.979	5.58	2.85			27.0					3.49	6.86		

Sheet 2 Span 6

Test No.	Test Series	Girder	Direc. of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B. at 1 R.P.S.	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L.L. Defl at Dist "P"	Stat L.L. Defl Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	Speed R.P.S. "N"	Speed M.P.H	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat. Defl H Blow $D_N N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec DL	LL	Imp	Total
B-412	3	N	E	J, D	6609	1690	353.0	2623	11	P	1389	.951	5.42	287	1.51	2127	27.4	.040	.0070	5.71	4.2	3.54	667	.28	1049
B-545	2	"	E	"	6608	"	"	262.9	14	"	1358	.924	5.26	291	1.77	2488	243	.026	0096	271	2.8	"	647	.18	10.19
A-566	2	"	E	"	6610	"	"	262.3	13	"	1363	.929	528	2.91	1.84	2594	248	016	0104	1.54	1.7	"	6.49	11	10.14
A-685	3	"	W	"	6613	"	"	300.4	12	"	1390	.950	5.41	2.87	1.90	26.81	275	.037	.0110	3.36	3.9	"	665	26	10.45
A-551	2	"	W	"	6608	"	"	301.0	13	"	1470	.990	5.64	2.84	1.95	27.05	305	.041	.0116	353	4.1	"	684	28	10.66
A-541	2	"	W	"	6607	"	"	301.0	12	"	144.8	.993	565	2.83	1.96	27.65	333	.033	.0118	2.79	3.3	"	695	23	1072
B-399	3	"	W	"	6609	"	"	301.0	13	"	1410	.981	559	2.84	205	28.83	295	.034	.0129	263	34	"	6.88	.23	10.65
A-681	3	"	W	"	6607	"	"	301.0	12	"	1410	.940	5.35	2.88	207	2921	29.5	.040	.0131	3.05	4.3	"	658	.28	10.40
A-697	3	"	E	"	6607	"	"	2664	11	"	137.0	.896	5.10	293	220	3100	25.5	.028	.0148	189	3.1	"	6.27	.19	9.90
B-409	3	"	E	"	6611	"	"	266.4	11	"	1380	.944	538	2.88	223	3149	265	.038	.0152	250	3.9	"	662	.26	10.42
B-404	3	"	E	"	6607	"	"	262.3	11	"	135.0	.884	504	294	2.29	32.30	235	.037	.0160	2.31	42	"	6.20	.26	10.00
A-576	2	"	W	"	6610	"	"	3010	11	"	1410	1039	5.86	274	2.42	3412	295	.059	.0179	324	5.8	"	7.21	.42	11.17
A-546	2	"	W	"	6600	"	"	292.0	7	"	140.5	1.003	5.7	282	2.55	35.95	29.0	.066	.0199	3.31	6.6	"	7.02	.46	1102
A-553	2	"	E	"	6607	"	"	2629	13	"	1390	.911	5.19	2.91	2.56	3602	275	.073	.0200	3.65	81	"	6.38	.52	10.44
		Average		E Bound		1690	3530	2636			137.2	920	5.33	291			25.7					3.54	656		
				W. Bound		1690	3530	299.6			141.0	.985	5.60	2.83			295					3.54	689		
A-536	2	N	W	K5BI	6507	1560	297.5	247.3	8	P	1452	.914	5.20	2.91	1.98	2793	34.0	.041	.0110	3.74	45	3.54	640	.29	10.23
A-567	2	"	W	"	6508	"	"	265.8	9	"	1383	.911	5.19	2.91	2.06	29.08	27.1	.030	.0119	2.52	33	"	640	.21	10.15
B-413	3	"	W	"	6510	"	"	262.9	7	"	139.2	.879	501	294	207	2922	28.0	050	.0120	2.40	5.7	"	6.16	35	10.05
B-403	3	"	W	"	6508	"	"	223.1	8	"	138.5				208	2936	27.3	.019	.0121	157		"			
A-687	3	"	W	"	6508	"	"	2629	7	"	142.3	874	498	294	225	3170	31.1	.024	.0142	169	27	"	6.13	.17	984
A-333	1	"	E	" II	6518	"	3030	2382	7	"	133.0	.883	5.04	2.98	229	32.26	21.8	048	.0147	3.26	5.4	3.31	620	.33	984
A-698	3	"	W	" II	6517	"	"	2629	7	"	1463	887	5.05	293	2.32	32.61	351	.053	.0151	3.51	60	354	6.21	.37	1002
A-319	1	"	E	" I	6508	"	2975	238.2	7	"	1366	863	4.91	299	239	3375	25.4	.082	.0170	4.24	9.6	3.31	604	.57	9.92

Sheet 3 Span 6

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No.	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D			R.P.S. 'N'	M.P.H	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-306	1	N	E	K5B I	6507	1560	2975	2382	-	P	1362	863	491	299	259	3652	250	085	0189	444	99	3.31	604	60	9.95
A-554	2	-	W	" II	6524	-	303.0	265.8	3	"	1417	919	524	290	290	4084	305	.109	.0235	464	119	3.54	645	.77	1076
		Average Type I-			E B.	1560	2975	2382			1364	863	491	299			252					3.31	604		
					W.B.	1560	2975	2524			1484	.894	509	292			295					354	626		
				Type II	E.B	1560	303.0	2382			133.0	.883	503	298			218					331	619		
					W.B	1560	303.0	2644			1440	903	514	291			328					354	632		
A-528	2	N	W	K3Q	6486	1645	295.5	200.1	12	P	1370	.789	449	3.04	192	2704	264	023	0109	211	3.0	354	552	17	923
A-568	2	-	W	"	6486	"	"	2004	7	"	1373	839	477	300	200	2819	267	036	0118	305	43	354	587	25	966
A-321	1	-	W	"	6485	"	"	199.6	7	"	1368	824	470	3.04	227	3206	264	092	0152	60	112	331	578	.65	974
B-405	3	N	W	K3R	6500	1460	278.0	198.8	7	P	1362	796	453	3.04	229	3231	253	020	0152	132	25	354	5.57	14	9.25
A-322	1	N	W	K3L	6473	1600	2740	191.4	7	P	134.8	.830	473	303	209	2945	242	043	.0127	338	52	331	5.82	30	9.43
A-318	1	"	W	K3K	6465	"	"	190.4	7	"	1310	822	468	304	229	3234	204	051	0152	335	62	331	576	36	943
A-312	1	N	W	K-K	6442	1210	2420	1592	4	P	1340	.722	411	316	256	3432	244	073	0144	507	10.0	331	506	.51	888
A-330	1	-	E	"	6444	"	"	966	3	"	1285	.680	387	3.17	274	36.71	18.9	041	0165	248	60	3.31	476	29	836
A-316	1	N	E	KH	6425	1260	236.0	105.0	3	P	1322	.654	372	317	202	2704	226	040	0108	370	61	331	458	28	822
A-326	1	-	W	"	6425	"	"	158.0	4	"	1331	713	406	316	221	2962	23.5	037	0129	2.87	5.2	331	499	.26	8.56
A-309	1	N	E	L2D	6241	2150	367.0	234.2	-	F	1374	914	520	2.95	104	1282	232	.031	0041	756	34	3.31	640	22	993
A-682	3	-	E	"	6241	"	"	229.6	79	"	1327	.853	486	296	1.19	1468	185	031	0054	574	3.6	354	598	22	974
B-410	3	"	E	"	6246	"	"	227.5	61	"	1339	936	533	288	1.21	1488	19.7	021	.0056	375	22	354	656	14	1024

Sheet 4 Span 6

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D			R.P.S. 'N'	M.P.H	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-696	3	N	E	L2D	6246	2155	3670	2707	73	F	1380	912	519	291	129	1587	23.8	020	0063	317	2.2	354	638	14	1006
B-400	3	-	E	-	6244	"	-	2159	77	-	1328	868	494	295	130	1597	186	043	0064	672	49	3.54	608	.30	9.92
A 565	2	"	W	-	6244	"	-	3022	79	"	1407	970	5.52	285	132	1618	265	047	0066	712	50	3.54	679	.34	1067
A-323	1	-	E	"	6246	"	-	2394	-	-	1330	.946	538	291	145	1785	188	.059	0080	737	62	3.31	662	41	1034
A-325	1	-	W	L2D	6246	-	"	3048	-	"		1194	680	266	154	1897		046	0090	51		331	836		
(DH)				H10AI	25	1270	3350	2713		-					1.69	1897		031	.0065	48					
A-322	1	-	W	L2D	6248	2155	3670	3048	-	"	1388	944	538	291	154	1894	246	053	.0090	588	56	331	662	.43	1036
A-548	2	-	W	"	6247	"	-	3048	99	"	1350	977	556	285	156	1921	208	.041	0093	441	4.2	354	684	29	1067
A 315	1	"	E	"	6240	-	-	2294	64	-	1304	901	512	295	170	2091	162	.035	.0110	318	3.9	331	630	25	986
A-689	3	-	W	-	6240	"	-	3048	74	"	1387	924	527	291	189	2321	246	.043	0136	316	47	354	648	30	1032
B-398	3	"	W	"	6240	-	-	3048	57	"	1368	952	542	287	194	2386	23.6	.033	0144	229	35	354	667	23	1044
B-414	3	"	E	"	6240	"	-	2342	54	"	1310	900	512	292	197	2428	168	043	0148	290	4.8	354	630	.30	1014
A 547	2	"	E	-	6244	"	-	2342	65	"	1373	932	531	2.89	199	2448	231	030	0150	200	32	354	653	[illegible]	1028
A-688	3	-	E	-	6245	-	-	2551	50		1397	868	494	295	201	2475	255	.021	.0154	136	2.4	354	608	.15	977
A-540	2	-	E	"	6240	-	-	2311	77	"	1300	896	510	293	203	2503	158	041	0157	261	46	354	6.27	.29	1010
A-573	2	-	E	-	6247	-	-	2284	44	"	1309	892	508	293	204	2504	167	.043	0158	272	48	354	625	30	1009
A 692	3	-	W	-	6245		-	3048	66	"	1360	944	538	288	213	2625	228	042	0172	244	44	354	662	29	1045
A 550	2	-	W	-	6240	"	-	3048	-	-	1444	997	567	282	218	2677	302	041	0181	226	41	354	697	29	1080
A-530	2	-	E	-	6246	-	-	2300	85	-	1337	851	485	297	221	2719	195	037	0186	700	44	354	596	26	966
A-539	2	"	W	"	6246	-	-	3048	47		1467	1041	593	274	229	2813	325	051	0200	255	49	354	729	36	1019
A-575	2	-	E	-	6240	-	-	2304	51	-	1349	908	512	291	253	3113	207	088	0244	361	97	354	6.30	61	1045
A-691	3	-	W	-	6241	-		2544	46	"	1380	946	538	288	254	3118	238	095	0246	386	100	354	662	66	082
		Average E Bound				2155	3670	2350			1340	898	[illegible]	295			208					349	[illegible]		
				W Bound		2155	3670	2995			1395	966	550	284			263					349	677		

Sheet 5 Span 6

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L.L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H.	Dist "H" (Ft)	Oscil (ins)				D.L	L.L	Imp.	Total
A-555	2	N	E	L2B	6203	1845	364.0	210.7	101	F	1339	.848	4.83	2.97	1.03	12.61	19.7	.016	.0035	4.57	1.9	3.54	5.94	.11	9.59
B-415	3	"	W	"	6204	"	"	281.8	83	"	136.0	.910	5.13	2.91	1.05	12.89	21.8	.005	.0036	1.39	0.5	3.54	6.31	.03	9.88
A-328	1	"	E	"	6201	"	"	211.9	60	"	131.0	.871	4.96	2.99	1.07	13.19	16.8	.028	.0037	7.57	3.2	3.31	6.10	.20	9.61
A-313	1	"	W	"	6200	"	"	287.0	53	"	142.0	1.010	5.70	2.85	1.38	16.93	27.8	.040	.0062	6.45	4.0	3.31	7.01	.28	10.60
A-542	2	"	E	"	6207	"	"	211.5	81	"	140.3	.890	5.07	2.93	1.41	17.40	26.1	.069	.0065	10.62	7.7	3.54	6.24	48	10.26
A 552	2	"	W	"	6206	"	"	287.1	–	"	134.3	.950	5.41	2.87	1.50	18.45	20.1	.059	.0073	8.08	6.2	3.54	6.65	.41	10.60
A-529	2	"	W	"	6207	"	"	287.1	96	"	135.0	.864	4.92	2.95	1.53	18.86	20.8	.038	.0076	5.00	4.4	3.54	6.05	.27	9.86
A-572	2	"	W	"	6204	"	"	287.1	65	"	133.0	.917	5.23	2.91	1.65	20.33	18.8	.027	.0089	3.03	3.0	3.54	6.43	.19	10.16
A-532	2	"	E	"	6203	"	"	206.4	–	"	131.2	.839	4.77	2.99	1.71	21.04	17.0	.026	.0095	2.74	3.1	3.54	5.87	.18	9.59
B-406	3	"	W	"	6206	"	"	287.1	64	"	136.7	.945	5.38	2.87	2.08	25.56	22.5	.035	.0141	2.48	3.7	3.54	6.62	.24	10.40
A-569	2	"	E	"	6202	"	"	212.6	69	"	132.8	.885	5.04	2.93	2.26	27.81	18.6	.049	.0167	2.93	5.5	3.54	6.20	.34	10.08
	Average			E Bound		1845	364.0	210.6			133.6	.867	4.93	2.96			19.4					3.49	6.06		
				W Bound		1845	364.0	286.2			136.7	.933	5.30	2.89			21.9					3.50	6.52		
A-558	2	N	W	H10A II	146	1390	335.0	260.0	6	F	142.5	.977	5.56	2.85	1.00	11.19	32.8	.014	.0024	5.83	1.4	3.54	6.83	.10	10.47
A-557	2	"	W	" II	146	"	"	260.0	6	"	141.5	.951	5.42	2.87	1.21	13.57	31.8	.017	.0036	4.72	1.8	3.54	6.67	.12	10.33
A-671	2	"	E	" II	169	"	"	222.5	–	"	141.0	.900	5.12	2.92	1.22	13.75	31.3	.008	.0037	2.16	.9	3.54	6.30	.06	9.90
B-407	3	"	E	" II	169	"	"	228.1	77	"	137.3	.926	5.27	2.89	1.23	13.84	27.6	.010	.0037	2.70	1.1	3.54	6.48	.07	10.09
A-564	2	"	W	" II	146	"	"	260.0	6	"	144.0	.944	5.38	2.87	1.59	17.92	34.3	.026	.0062	4.19	2.8	3.54	6.62	.19	10.35
A-556	2	"	W	" II	146	"	"	260.0	6	"	146.0	.959	5.46	2.87	1.69	18.52	36.3	.047●	.0071	6.62●	4.9●	3.54	6.72	.35●	10.59●
A-325	1	"	W	L2D }	6246	2155	367.0	304.8	–	"		1.194	6.80	2.68	1.54	18.97		.046	.0090	5.1		3.31	8.36		
(D H.)		"		H10A·I)	25	1270	335.0	271.3		"		(D H)			1.69	18.97		.031	.0065	4.8					
A-308	1	"	W	H10A·I	5	"	"	241.3	–	"	133.0	.914	5.20	2.95	1.80	20.25	23.4	.043●	.0073	5.89●	4.7●	3.31	6.40	.30●	10.01●
A-562	2	"	W	" II	146	1390	"	260.0	6	"	144.8	.972	5.53	2.85	1.92	21.54	35.1	.022	.0090	2.44	2.3	3.54	6.80	.15	10.49

Sheet 6 Span 6

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L.L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec.			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)				D.L	L.L.	Imp.	Total
A-683	3	N	W	(H10A·II }	169	1390	335.0	273.4	62	F		1.084	6.17	2.75	2.00	22.6		.022	.0099	2.22		3.54	7.59		
(D H)		"		(G-46 H)	6866	2080	246.0	149.0					(D H)		2.21	22.6		.046	.0183	2.51					
A-680	3	"	E	H10-A III	174	1280	335.0	219.7	101	"	129.7	.851	4.85	2.97	2.06	23.19	19.4	.019	.0096	1.99	2.2	3.54	5.96	.12	9.62
A-690	3	"	E	" III	150	"	"	231.5	67	"	132.3	.877	5.00	2.95	2.10	23.63	22.0	.025	.0100	2.50	2.9	3.54	6.15	.18	9.87
A-538	2	"	E	" III	172	"	"	232.5	102	"	137.4	.959	5.46	2.87	2.16	24.26	27.7	.032	.0107	3.00	2.3	3.54	6.72	.22	10.48
A-559	2	"	W	" II	146	1390	"	260.0	6	"	147.2	.956	5.44	2.87	2.35	26.33	37.5	.042	.0134	3.09	4.4	3.54	6.69	.29	10.52
A 561	2	"	W	" II	146	"	"	260.0	6	"	144.8	.969	5.52	2.84	2.45	27.69	35.1	.054	.0148	3.65	5.5	3.54	6.79	.37	10.70
A-560	2	"	W	" II	146	"	"	260.0	6	"	148.0	.951	5.42	2.87	2.53	28.59	38.3	.065	.0158	4.11	6.8	3.54	6.67	.45	10.66
A-310	1	"	E	" II	169	"	"	209.5	-	"	129.5	.914	5.20	2.95	2.86	32.15	19.2	.105	.0202	5.19	11.5	3.31	6.40	.75	10.46
A-563	2	"	W	" II	146	"	"	260.0	6	"	147.0	.950	5.42	2.87	2.91	32.62	37.3	.088	.0209	4.21	9.3	3.54	6.67	.62	10.83
			Average	E	-Bound		335.0	224.0			134.5	.905	5.15	2.92			24.5					3.50	6.33		
				" W	"		335.0	258.1			143.9	.954	5.44	2.87			34.2					3.52	6.69		

● NOTE - These are free oscillations and not caused by the hammer blow.

SPAN NO. 7

A double track riveted through truss, 150 feet long, and 32 feet deep, center to center of chords. See Fig. 39.

Fortunately this was the only double track span tested. It will be realized that, with a load on one track only which was the condition when the test runs occurred, the deflection of the near truss will be much greater than that of the other. The tracks on this span are 13 ft. centers, and the trusses are 30 ft., 6 in. apart, so that the distribution of the live load between the heavily and lightly loaded trusses should be 71 and 29 per cent. If, under such a distribution, the natural frequency of the heavily loaded truss were 4.0, the frequency of the lightly loaded truss would be about 5.0. Therefore the free oscillations cannot be in phase, although the forced oscillations may be. The difference in deflection must necessarily distort the transverse bracing which in this case consists of the deep, stiff floorbeams and the top struts, and this distortion undoubtedly sets up torsional oscillations.

If the floorbeams were hinged at their connections, we might expect the oscillations in the heavy and light trusses to be in the proportion of 71 to 29, but actually they are more nearly in the ratio of 60 to 40, and while they are fairly uniform and regular in the heavy truss, those in the light truss are usually broken up as to period.

On this span we had an opportunity to measure the deflection under a string of heavily loaded cars placed on one track. The car weights were known, and the axle spacing measured. The deflection of the heavily loaded truss was found to be .3065 inch, and for the lightly loaded truss it was .1286 inch, giving an actual distribution of 70.6 and 29.4 per cent. From the average of the tests with the H5-O Class of locomotives at low speed, the distribution for eastward movements was found to be 70.8 and 29.2 per cent, and for westward, 70.7 and 29.3 per cent. From the special test train the deflection factor was found to be .786, giving a dead load deflection of .283 inch, and an unloaded frequency of 6.51.

The calculated hammer blow deflections, D_h, are as follows:

	D_h			D_h	
Class of Locomotive	*Heavy Truss*	*Light Truss*	*Class of Locomotive*	*Heavy Truss*	*Light Truss*
J1-D	.001578	.000657	L2-D	.001946	.000810
K5	.001551	.000646	L2-B	.001681	.000700
K5-B	.001449	.000604	H10-A—Type I	.001161	.000484
K3-Q	.001531	.000637	H10-B— " I	.001071	.000447
K3-J, K3-K, K3-L	.001480	.000616	H6-A	.001914	.000797
K-N	.001119	.000466	H5-O, H5-L	.001905	.000793
K-B	.001166	.000487			

In Table XXI, giving the results of the tests, the oscillations are first shown just as they were taken from the record but due to the improper distribution, they are not suitable for determining the damping factor Δ, in which we are especially interested. We can assume, however, without much error, that the total oscillation in the two trusses, is a measure of the total energy input, so that if we take the sum of the two oscillations and redistribute them in the proportion of 70.6 and 29.4, we will more nearly have the condition which would have obtained had there been no transverse bracing, and have a means of arriving at a safer value of the damping factor. The oscillations, as corrected in this manner, are given in the adjoining column in the table. Using the corrected values for tests near synchronous speed we get the following:

L2-D Loc.; $N = 3.89$ r.p.s.; Frequency, n, of Heavy Truss $= 3.99$; $\frac{N}{n} = .970$

Test	*Oscillation*		*Dynamic Magnifier*	*Damping*	*Damping Constant*
No.	*Measured*	*Corrected*	*k*	*Factor* Δ	$p = \frac{\Delta}{2n}$
A-487	.060	.053			
B-227	.121	.128	4.36	.229	.0286

L2-D Loc.; $N = 4.08$ r.p.s.; Freq. n, of Heavy Truss $= 3.96$; $\frac{N}{n} = 1.03$

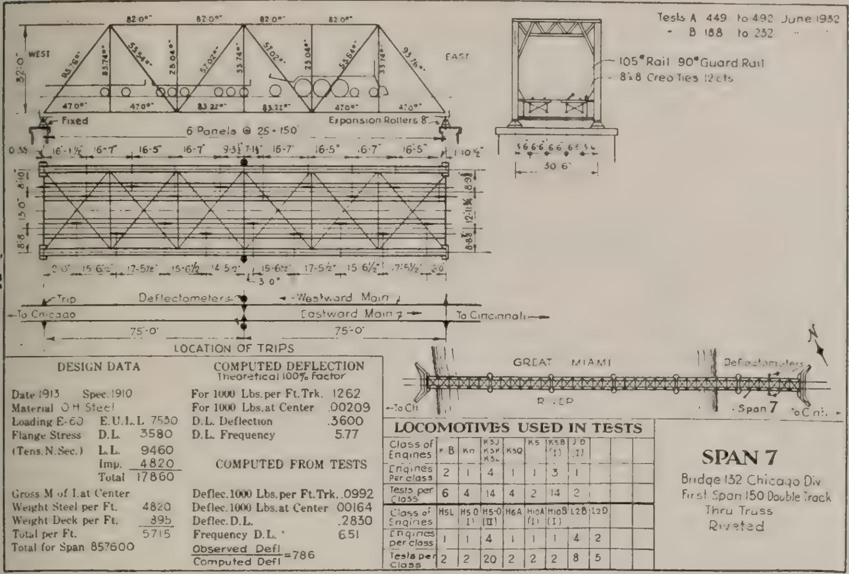
Test	*Oscillation*		*Dynamic Magnifier*	*Damping*	*Damping Constant*
No.	*Measured*	*Corrected*	*k*	*Factor* Δ	$p = \frac{\Delta}{2n}$
A-469	.068	.056			
B-208	.124	.136	4.18	.224	.0283

L2-B Loc.; $N = 3.82$ r.p.s.; Freq. n, of Heavy Truss $= 4.00$; $\frac{N}{n} = .955$

Test	*Oscillation*		*Dynamic Magnifier*	*Damping*	*Damping Constant*
No.	*Measured*	*Corrected*	*k*	*Factor* Δ	$p = \frac{\Delta}{2n}$
A-458	.062	.046			
B-197	.096	.112	3.92	.242	.0302

The derived values of the damping constant, p, agree fairly well, and are about what we should expect. In Span No. 8, which is a single track truss 140 ft. long and of similar construction, p was found to be .0285. Using this, the theoretical values of the dynamic magnifiers and oscillations have been computed for two frequencies, $n = 3.98$ corresponding to the heaviest locomotives, and $n = 4.30$ for the lighter loads, as shown in Fig. 40. The corrected measured oscillations in the heavy truss are plotted for nine classes of locomotives and considering that this is an unsymmetrically loaded span, they agree surprisingly well.

In Table XXI, the values of $D_h N^2$, the static hammer blow deflection, are computed on the assumption that the hammer blow is distributed between the heavily and lightly loaded trusses in the proportion of .706 and .294, and the dynamic magnifiers are computed from these values of $D_h N^2$ and the corrected oscillations. The impact percentages, however, are calculated from the actual measured oscillations and the deflection, D, giving high impacts in the lightly loaded truss.



DESIGN DATA

Date 1913 Spec. 1910
Material O H Steel
Loading E-60 E.U.L.L 7530
Flange Stress D.L. 3580
(Tens. N. Sec.) L.L. 9460
Imp. 4820
Total 17860
Gross M of I at Center
Weight Steel per Ft. 4820
Weight Deck per Ft. 895
Total per Ft. 5715
Total for Span 857600

COMPUTED DEFLECTION
Theoretical 100% Factor

For 1000 Lbs. per Ft. Trk. .1262
For 1000 Lbs. at Center .00209
D.L. Deflection .3600
D.L. Frequency 5.77

COMPUTED FROM TESTS

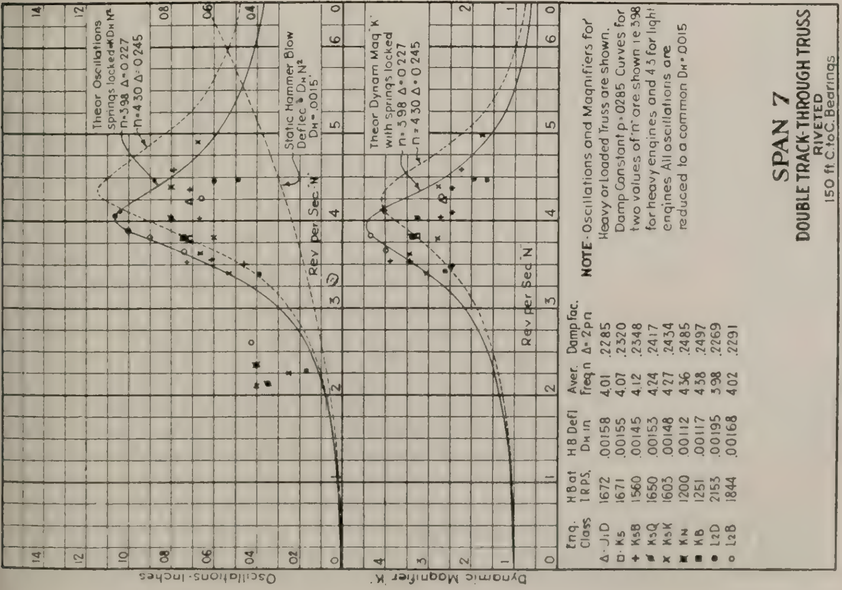
Deflec. 1000 Lbs. per Ft. Trk. .0992
Deflec. 1000 Lbs. at Center .00164
Deflec. D.L. .2830
Frequency D.L. 6.51
$\frac{\text{Observed Defl}}{\text{Computed Defl}} = 786$

LOCOMOTIVES USED IN TESTS

Class of Engines	KB	Kn	K3J K3K K3L	K3Q	K5	K5B (I)	J D (I)			
Engines Per class	2	1	4	1	1	3	1			
Tests per Class	6	4	14	4	2	14	2			
Class of Engines	H5L	H5 0 (I)	H5-0 (II)	H6A	H10A (I)	H10B (I)	L2B	L2D		
Engines per class	1	1	4	1	1	1	4	2		
Tests per Class	2	2	20	2	2	2	8	5		

SPAN 7
Bridge 132 Chicago Div
First Span 150 Double Track
Thru Truss
Riveted

Fig. 39



Eng. Class	H B at 1 RPS.	H B Defl D_H in	Aver. Freq n	Damp fac. $\Delta = 2pn$
Δ · J1D	1672	.00158	4.01	.2285
□ · K5	1671	.00155	4.07	.2320
+ K5B	1560	.00145	4.12	.2348
◢ K3Q	1650	.00153	4.24	.2417
× K3K	1603	.00148	4.27	.2434
⊠ KN	1200	.00112	4.36	.2485
■ KB	1251	.00117	4.38	.2497
● L2D	2153	.00195	3.98	.2269
○ L2B	1844	.00168	4.02	.2291

NOTE - Oscillations and Magnifiers for Heavy or Loaded Truss are shown. Damp Constant p = .0285 Curves for two values of 'n' are shown i.e 3.98 for heavy engines and 4.3 for light engines All oscillations are reduced to a common $D_H = .0015$

SPAN 7
DOUBLE TRACK-THROUGH TRUSS
RIVETED
150 ft. C. to C. Bearings

Fig. 40

TABLE XXI

150 Ft DOUBLE TRACK RIVETED TRUSS SPAN- BR 132 CHICAGO DIV

Sheet 1 Span 7

Test		Girder	Direc of Movement	Locomotive					Cars		Stat. L.L. Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) 'D'			R.P.S. 'N'	M.P.H	Meas Oscill (ins)	Corr Oscill (ins)				DL	LL	Imp	Total
A-479	I	S	E	J1D	6606	1672	351.5	248.1	11	P	122.4	.464	4.68	4.01	4.23	59.64	.068	.076	.0283	2.69	14.7	3.58	5.85	.86	10.29
B-219	I	N	"	"	"	"	"	"	"	-	111.6	.189	1.91	5.04	4.24	59.76	.040	.032	.0118	2.75	21.2	"	2.39	.51	6.48
A-449	I	S	W	K5	6525	1671	303.0	255.4	-	P	120.0	.182	1.83	5.08	3.81	53.72	.048	.030	.0094	3.19	26.4	3.58	2.29	.60	7.47
B-188	I	N	"	"	"	"	"	"	"	-	124.8	.440	4.44	4.07	3.81	53.72	.055	.073	.0225	3.24	12.5	"	5.55	.69	9.82
A-450	I	S	E	K5BI	6506	1560	297.5	225.8	-	P	124.4	.414	4.17	4.15	3.49	49.27	.041	.044	.0177	2.44	9.9	3.58	5.21	.52	9.31
B-189	"	N	"	"	"	"	"	"	"	"	124.1	.174	1.75	5.12	3.50	49.28	.022	.019	.0074	2.57	12.6	"	2.19	.28	6.05
A-489	"	S	W	"	6506	"	"	255.6	6	"	110.3	.180	1.81	5.09	3.50	49.36	.037	.029	.0074	3.92	20.5	"	2.26	.46	6.30
B-229	"	N	"	"	"	"	"	"	"	"	112.0	.460	4.64	4.02	3.53	49.76	.063	.071	.0181	3.92	14.1	"	5.80	.82	10.20
A-484	"	S	W	"	6505	"	"	255.3	11	"	99.6	.193	1.94	5.02	4.03	56.82	.029	.027	.0097	2.78	15.0	"	2.41	.36	6.35
B-224	"	N	"	"	"	"	"	"	"	"	100.9	.439	4.42	4.07	4.02	56.71	.062	.064	.0234	2.73	14.1	"	5.53	.78	9.89
A-470	"	N	W	"	6514	"	"	255.3	-	"	110.3	.435	4.38	4.09	4.09	57.62	.047	.059	.0242	2.44	10.8	"	5.48	.59	9.65
B-210	"	S	"	"	"	"	"	"	"	"	103.0	.200	2.02	4.98	4.04	56.82	.037	.025	.0098	2.55	18.5	"	2.53	.47	6.58
A-455	"	S	W	"	6505	"	"	258.4	10	"	124.4	.187	1.88	5.05	4.12	58.03	.055	.042	.0102	4.12	29.4	"	2.35	.69	6.62
B-194	"	N	"	"	"	"	"	"	"	"	123.2	.429	4.32	4.10	4.12	58.05	.087	.100	.0246	4.07	20.3	"	5.40	1.10	10.08
A-465	"	S	E	"	6514	"	"	225.3	-	"	111.0	.384	3.87	4.24	4.38	61.67	.056	.068	.0278	2.44	14.6	"	4.84	.71	9.13
B-204	"	N	"	"	"	"	"	"	"	"	122.0	.174	1.75	5.12	4.34	61.12	.040	.028	.0113	2.47	22.9	"	2.19	.50	6.27
A-478	"	N	E	"	6505	-	"	—	8	"	111.9	.187	1.88	5.05	4.65	64.08	.048	.032	.0124	2.58	25.7	"	2.35	.60	6.53
B-218	"	S	"	"	"	"	"	—	-	"	114.6	.423	4.26	4.12	4.58	64.54	.060	.076	.0304	2.50	14.0	"	5.33	.76	9.66
Average			E Bound-	Heavy Truss			211.2	160.0			116.1	.407	4.10	4.17								3.58	5.13		
					Light	Truss	86.3	65.3			119.3	.178	1.79	5.12								"	2.24		
			W Bound	Heavy Truss			211.2	181.9			111.6	.441	4.44	4.07								3.58	5.55		
					Light	Truss	86.3	74.3			109.3	.188	1.89	5.05								"	2.36		

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Test		Girder	Direc of Movement	Locomotive					Cars		Stat. L.L. Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec			
No.	Series			Class	Eng No.	H. B. at 1RPS.	Weight (Kips) Eng	Weight (Kips) Tender	No.	Kind	at Dist 'P'	Defl. (ins) 'D'			R.P.S. 'N'	M.P.H	Meas Oscill (ins)	Corr Oscill (ins)				D.L.	L.L	Imp.	Total
A-467	I	N	W	K3Q	6487	1650	295.5	186.5	–	P	110.3	.392	3.95	4.22	2.13	30.02	.026	.036	.0069	5.22	6.6	3.58	4.94	.33	8.85
B-206	"	S	"	"	"	"	"	"	"	"	111.2	.187	1.88	5.05	2.14	30.11	.025	.015	.0029	5.17	13.3	"	2.34	.31	6.23
A-472	"	N	E	"	6487	"	"	—	3	"	122.3	.122	1.23	5.44	4.04	56.92	.046	.034	.0104	3.27	37.7	"	1.53	.58	5.69
B-212	"	S	"	"	"	"	"	"	"	"	105.3	.377	3.80	4.26	4.04	56.98	.070	.082	.0250	3.28	18.6	"	4.75	.88	9.21
A-482	I	S	W	K3K	6467	1603	274.0	177.8	4	P	124.0	.157	1.58	5.22	2.09	29.42	.044	.016	.0027	5.92	28.0	3.58	1.98	.55	6.11
B-222	"	N	"	"	"	"	"	"	"	"	117.0	.397	4.00	4.20	2.10	29.61	.012	.040	.0065	6.07	3.0	"	5.00	.15	8.73
A-490	"	S	E	"	6464	"	"	115.8	3	"	107.6	.355	3.58	4.34	2.25	32.41	.021	.025	.0075	3.33	5.9	"	4.48	.26	8.32
B-230	"	N	"	"	"	"	-	"	"	"	109.6	.151	1.52	5.26	2.29	32.23	.015	.011	.0032	3.44	9.9	"	1.90	.19	5.67
A-474	"	N	W	K3L	6470	"	"	185.6	6	"	109.7	.393	3.96	4.22	3.39	47.76	.044	.052	.0170	3.06	11.2	"	4.95	.55	9.08
B-214	"	S	"	"	"	"	"	"	"	"	118.8	.167	1.68	5.15	3.44	48.55	.030	.022	.0073	3.00	17.9	"	2.10	.38	6.06
A-459		S	W	K3J	6458	"	"	191.3	6	"	124.2	.174	1.75	5.12	3.62	51.07	.037	.027	.0081	3.33	21.2	"	2.18	.46	6.22
B-198		N	"	"	"	"	"	"	"	"	108.0	.403	4.06	4.18	3.62	51.04	.056	.066	.0193	3.42	13.9	"	5.08	.71	9.37
A-492		S	W	"	6458	"	"	185.3	4	"	114.6	.184	1.85	5.07	3.79	53.41	.042	.024	.0089	2.70	22.8	"	2.31	.53	6.42
B-232		N	"	"	"	"	"	"	"	"	114.3	.384	3.87	4.24	3.79	53.41	.041	.059	.0213	2.77	10.7	"	4.84	.52	8.94
A-475		N	E	K3K	6464	"	"	113.2	3	"	113.0	.156	1.57	5.22	4.41	62.12	.037	.034	.0121	2.81	23.7	"	1.96	.46	6.00
B-215		S	"	"	"	"	"	"	"	"	103.3	.372	3.75	4.28	4.37	61.67	.077	.080	.0283	2.83	20.7	"	4.69	.97	9.24
A-460		S	E	"	6464	"	"	115.8	3	"	117.7	.347	3.50	4.36	5.04	71.07	.056	.066	.0376	1.75	16.1	"	4.38	.70	8.66
B-199		N	"	"	"	"	"	"	"	"	111.0	.108	1.09	5.54	4.90	69.06	.037	.027	.0156	1.70	34.2	"	1.36	.47	5.41
	Average			E. Bound-	Heavy	Truss	194.5	81.6			109.5	.358	3.61	4.33								3.58	4.51		
					Light	Truss	79.5	33.3			111.3	.138	1.39	5.34								"	1.74		
				W. Bound	Heavy	Truss	194.5	131.4			112.2	.394	3.97	4.22								3.58	4.96		
					Light	Truss	79.5	53.6			120.4	.171	1.72	5.14								"	2.15		

Sheet 3 Span 7

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No.	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D	E.U.L.L (Kips)	Loaded Frequency 'n'	R.P.S. 'N'	M P H	Meas Oscill (ins)	Corr Oscill (ins)	Stat Defl H Blow D, N² at Center	Dynamic Magnifier 'k'	Impact %	DL	LL	Imp	Total
A-452	I	S	W	KN	6449	1200	246.0	140.1	-	P	103.2	.156	1.57	5.22	2.34	31.29	.021	.013	.0025	5.20	13.4	3.58	1.96	.36	5.90
B-191	-	N	·	·	·	·	-	·	·	·	106.6	.342	3.45	4.38	2.34	31.30	.022	.030	.0061	4.92	6.4	·	4.31	.28	8.17
A-477	-	N	W	·	6449	·	-	147.0	4	-	106.2	.355	3.58	4.34	3.81	51.01	.044	.055	.0163	3.37	12.3	·	4.48	.55	8.61
B-217	-	S	..	·	·	..	..	·	-	·	106.2	.152	1.53	5.26	3.79	50.76	.034	.023	.0067	3.43	22.2	-	1.91	.42	5.91
A-486	I	S	E	KB	6416	1251	222.8	76.5	3	P	112.1	.133	1.34	5.37	2.28	30.48	.009	.005	.0025	2.0	[illegible]	3.58	1.68	.11	5.37
B-226	-	N	·	·	-	·	-	·	·	·	114.0	.321	3.24	4.46	2.27	30.42	.009	.013	.0061	2.13	2.8	·	4.05	.11	7.74
A-463	-	S	W	·	6416	·	-	136.6	4	·	111.7	.131	1.32	5.38	3.47	46.41	.017	.014	.0059	2.47	12.9	-	1.65	.21	5.44
B-202	·	N	·	·	·	·	·	..	·	·	112.2	.353	3.56	4.35	3.37	45.17	.032	.035	.0133	2.63	9.1	·	4.45	.40	8.43
A-456	-	S	E	·	6416	·	-	76.5	4	·	108.7	.357	3.60	4.33	4.48	59.99	.033	.038	.0235	1.62	9.2	·	4.50	.41	8.49
B-195	·	N	..	·	..	..	·	..	·	..	107.2	.136	1.37	5.35	4.49	60.09	.021	.016	.0098	1.61	15.4	·	1.71	.26	6.55
A-487	I	S	W	L2D	6226	2153	367.0	270.7	59	F	114.2	.224	2.26	4.87	3.89	47.84	.060	.053	.0123	4.31	2.7	3.58	2.83	.07	6.48
B-227	·	N	·	·	-	·	-	·	..	-	117.4	.470	4.74	3.99	3.88	47.69	.121	.128	.0293	4.36	2.6	·	5.93	.15	9.66
A-469	-	N	E	-	6229	-	-	213.2	32	·	115.0	.193	1.94	5.02	4.04	49.67	.068	.056	.0132	4.24	3.5	·	2.43	.09	6.10
B-208	·	S	-	·	-	-	-	-	-	-	112.9	.482	4.86	3.96	4.12	50.74	.124	.136	.0331	4.11	2.6	·	6.07	.16	9.81
B-209	·	S	E	·	6226	-	-		47		112.0	.465	4.69	4.00	4.47	54.97	.069	.076	.0390	1.92	1.5	-	5.86	.09	9.53
	Average			E-Bound	Heavy	Truss	260.6	151.4			112.4	.478	4.82	3.97								3.58	6.03		
					Light	Truss	106.4	79.8			115.0	.193	1.95	5.02								·	2.44		
				W-Bound	Heavy	Truss	260.6	192.2			117.4	.470	4.74	3.99								3.58	5.93		
					Light	Truss	106.4	78.5			114.2	.224	2.26	4.86								..	2.83		
A-481	I	S	E	L2B	6210	1844	364.0	253.4	51	F	117.0	.459	4.63	4.02	2.63	32.29	.039	.048	.0116	4.14	8.5	3.58	5.79	.49	9.86
B-221	·	N	·	·	..	·	·	·	·	..	112.8	.201	2.03	4.98	2.60	32.02	.029	.020	.0047	4.25	14.4	·	2.54	.36	6.48

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Test				Locomotive					Cars		Stat. L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No.	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D	E U L L (Kips)	Loaded Frequency 'n'	R.P.S. 'N'	M P H	Meas Oscill (ins)	Corr Oscill (ins)	Stat Defl H Blow D, N² at Center	Dynamic Magnifier 'k'	Impact %	DL	LL	Imp	Total
A-473	I	N	W	L2B	6215	1844	364.0	266.2	61	F	117.4	.458	4.62	4.03	3.66	45.01	.075	.092	.0225	4.09	16.4	3.58	5.78	.95	10.31
B-213	·	S	-	..	-	-	..	-	·	-	119.1	.218	2.20	4.88	3.66	45.01	.055	.038	.0094	4.04	25.2	-	2.75	.69	7.02
A-458	·	S	W	-	6209	·	..	263.5	60	-	115.6	.197	1.99	5.00	3.84	47.19	.062	.046	.0103	4.46	31.5	..	2.49	.78	6.85
B-197	·	N	-	-	..	-	·	..	·	-	115.8	.467	4.71	4.00	3.82	47.01	.096	.112	.0245	4.57	20.6	-	5.89	1.21	10.68
A-454	-	S	E	·	6214	-	-	253.2	-	·	118.6	.454	4.58	4.04	4.27	52.52	.096	.083	.0306	2.71	21.1	-	5.73	1.21	10.52
B-193	-	N	-	·	·	-	..	·	·	·	118.5	.187	1.88	5.05	4.27	52.52	.022	.035	.0128	2.73	11.7	·	2.35	.27	6.20
Average			E Bound		Heavy	Truss	258.4	179.8			117.8	.457	4.61	4.03								3.58	5.76		
					Light	Truss	105.6	73.5			115.6	.194	1.96	5.02								·	2.45		
			W.	Bound	Heavy	Truss	258.4	188.0			116.6	.462	4.66	4.01								3.58	5.83		
					Light	Truss	105.6	76.8			117.3	.207	2.09	4.94								-	2.61		
A-485	I	S	E	H10AI	4	1270	335.0	213.2	[illegible]	F	112.1	.441	4.45	4.07	1.06	11.91	.006	.005	.0013	3.84	1.4	3.58	5.56	.08	9.22
B-225	-	N	-	-	-	-	·	·	·	-	117.5	.187	1.88	5.05	1.06	11.86	.002	.003	.0005	6.00	1.1	·	2.35	.03	5.96
A-471	I	N	E	H10BI	232	1188	334.5	236.2	65	F	115.1	.182	1.83	5.08	1.57	17.69	.005	.004	.0011	3.64	2.7	3.58	2.19	.06	5.83
B-211	·	S	..	-	·	-	·	·	·	·	107.3	.441	4.45	4.07	1.56	17.55	.010	.011	.0026	4.24	2.3	-	5.56	.13	9.27
A-451	I	S	E	H6A	6106	2136	290.8	152.6	50	F	116.4	.392	3.96	4.22	1.45	16.28	.030	.030	.0040	7.50	7.6	3.58	4.95	.38	8.91
B-190	·	N	-	·	-	·	-	·	·	·	113.4	.144	1.45	5.30	1.44	16.18	.012	.012	.0017	7.05	8.3	·	1.81	.15	5.44
A-491	I	S	E	H5-0 I	6702	2092	275.3	—	16	F	108.3	.357	3.60	4.33	0.52	5.86	.001	.001	.0005	2.00	0.3	3.58	4.50	.01	8.09
B-231	·	N	-	·	·	·	·	—	·	-	121.8	.143	1.44	5.30	0.52	5.82	.000	.000	.0002	-	0	·	1.80	0	5.38
A-464	·	S	E	H5-0 II	6048	·	·	148.3	28	-	=	.394	3.97	4.21	0.56	6.32	.025	.022	.0006	3.67	6.3	·	4.96	.31	8.85
B-203	·	N	·	..	..	·	·	-	-	..	—	.171	1.72	5.15	0.56	6.29	.006	.009	.0003	3.00	3.5	-	2.15	.08	5.81

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Test No.	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1 RPS.	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No	Cars Kind	Stat. L.L Defl at Dist "P	Stat. L.L Defl Defl (ins) "D	E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed R.P.S. 'N'	Speed M.P.H	Hammer Blow Meas Oscill (ins)	Hammer Blow Corr Oscill (ins)	Stat Defl H Blow $D_h N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens Net Sec D.L	L L	Imp	Total
A-483	1	S	W	H5-o II	6709	2092	275.3	125.8	55	F	119.7	.136	1.37	5.35	1.00	11.25	.006	.005	.0008	7.50	4.4	3.58	1.71	.08	5.37
B-223	"	N	"	"	"	"	"	"	"	"	108.3	.357	3.60	4.33	.99	11.13	.010	.011	.0019	5.28	2.8	"	4.50	.12	8.20
A-461	"	S	E	"	6713	"	"	143.8	2	"	107.9	.363	3.66	4.31	1.15	12.95	.010	.035	.0025	13.20	2.8	"	4.57	.13	8.28
B-200	"	N	"	"	"	"	"	"	"	"	116.0	.146	1.47	5.30	1.15	12.96	Free .040	.015	.0011	13.64	27.5	"	1.84	.50	5.92
A-488	"	S	E	"	6713	"	"	152.3	5	"	–	.438	4.44	4.08	1.25	14.01	.007	.008	.0029	2.76	1.6	"	5.55	.09	9.22
B-228	"	N	"	"	"	"	"	"	"	"	–	.177	1.78	5.11	1.24	13.90	.005	.004	.0012	3.33	2.8	"	2.22	.06	5.86
A-457	"	S	W	"	6713	"	"	140.3	4	"	116.2	.159	1.60	5.21	1.85	20.74	.010	.009	.0027	3.33	6.3	"	2.00	.13	5.71
B-196	"	N	"	"	"	"	"	"	"	"	125.8	.401	4.05	4.19	1.91	21.48	.022	.023	.0069	3.33	5.5	"	5.06	.28	8.92
A-476	"	N	E	"	6713	"	"	150.6	1	"	109.9	.146	1.47	5.30	2.03	22.77	.007	.008	.0032	2.50	4.8	"	1.84	.09	5.51
B-216	"	S	"	"	"	"	"	"	"	"	115.8	.370	3.73	4.29	2.02	22.75	.019	.018	.0078	2.31	5.1	"	4.66	.14	8.38
A-468	"	N	W	"	6048	"	"	141.2	11	"	111.0	.355	3.58	4.34	2.06	23.10	.016	.018	.0080	2.25	4.5	"	4.48	.20	8.26
B-207	"	S	"	"	"	"	"	"	"	"	117.5	.151	1.52	5.26	2.06	23.16	.009	.007	.0034	2.06	6.0	"	1.90	.11	5.59
A-466	"	N	W	"	6056	"	"	137.8	12	"	111.7	.386	3.89	4.24	2.09	23.48	.012	.013	.0083	1.57	3.1	"	4.86	.15	8.59
B-205	"	S	"	"	"	"	"	"	"	"	118.8	.174	1.75	5.12	2.09	23.52	.006	.005	.0035	1.43	3.5	"	2.19	.08	5.85
A-463	"	S	W	H5L	6002	"	275.7	127.0	12	"	119.8	.143	1.44	5.31	2.60	29.19	.019	.016	.0054	2.96	5.4	"	4.42	.24	8.24
B-192	"	N	"	"	"	"	"	"	"	"	115.3	.351	3.54	4.35	2.59	29.16	.036	.039	.0130	3.00	25.2	"	1.80	.45	5.83
A-462	"	S	E	H5-O II	6056	"	275.3	138.8	12	"	108.1	.145	1.46	5.30	2.67	30.05	.014	.011	.0057	1.93	9.7	"	1.82	.18	5.58
B-201	"	N	"	"	"	"	"	"	"	"	119.5	.339	3.42	4.39	2.69	30.24	.025	.028	.0136	2.06	7.4	"	4.28	.32	8.18
A-480	"	S	W	"	6056	"	"	134.6	16	"	–	.171	1.72	5.14	2.74	30.75	.019	.010	.0060	1.67	11.1	"	2.15	.24	5.97
B-220	"	N	"	"	"	"	"	"	"	"	–	.414	4.18	4.15	2.72	30.65	.015	.024	.0142	1.69	3.6	"	5.23	.19	9.00
Average			E. Bound	Heavy Truss			195.6	104.2			110.6	.377	3.80	4.26								3.58	4.85		
				Light Truss			79.9	42.5			115.1	.155	1.56	5.23								"	1.95		
			W. Bound	Heavy Truss			195.6	95.4			115.4	.377	3.80	4.26								3.58	4.85		
				Light Truss			79.9	39.0			118.0	.156	1.57	5.23								"	1.96		
NOTE:- The Average Engine and Tender Loads are distributed – 71% to Heavy Truss – 29% To Light Truss																									

SPAN NO. 8

A single track riveted through truss, 140 ft. long and 28 ft. deep, center to center of chords. There is a footwalk on both sides, which accounts for the larger dead load. See Fig. 41.

This bridge is in territory operated jointly with the Erie Railroad, and tests were taken of Erie trains. Attention is called to the heavy freight engines of that road, Classes S2 and S4. Each of these locomotives were counterbalanced differently, several of them having a very large amount of overbalance.

The abutments of this bridge are of stone and quite old. Under the northwest bearing one stone was cracked and there was a noticeable movement at that point. This is apparent in the measured deflections, and for that reason the deflections under the south truss should be used in arriving at the deflection factor. From the average loading and deflections the following values were found: Erie S4, .843; Erie S2, .833; L2-B, .844. Using an average value of .840, the dead load deflection is .2517 inch, the corresponding frequency being 6.90. The hammer-blow deflections, D_h, for the various locomotives and classes are as follows:

Class of Locomotive	D_h (Inches)
Erie S4, No. 3389	.003082
3390	.003904
3396	.003985
3400	.003648
3403	.004172
Erie S2, No. 3325	.002131
3326	.001995
3327	.002242
3334	.003038
3338	.002120
3345	.001995
3385	.003818

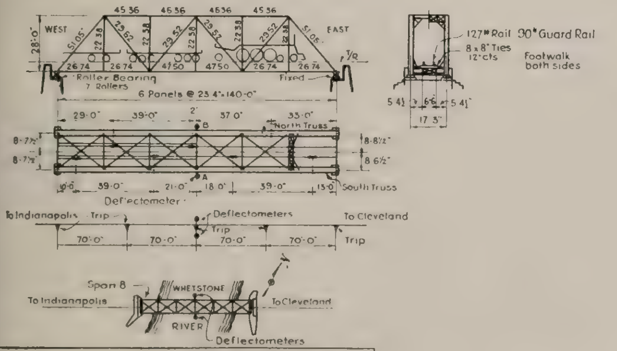
Class of Locomotive	D_h (Inches)
L2-D,—All	.002984
L2-B,— "	.002574
H10-B,—Type I	.001667
" II	.001116
H5-L,—All	.002963
Erie, —K5-A,—No. 2943	.002827
Erie, —K5, —No. 2924	.002846
—No. 2927	.003090
K5-B,—Type I	.002253
K3-P,— " I	.002738

The hammer-blow, at 1 r.p.s., for the Erie S4, No. 3403, is 2998 lb., that for No. 3396 is 2853 lb., both unusually large.

From Test A-1140, Erie S2, No. 3345, running at 3.54 r.p.s., the damping constant, *p*, was found to be .0319; from Test B-892, Erie S2, No. 3326, at 3.62 r.p.s., *p*, was found to be .0285, and from Test A-1141, an L2-B locomotive running at 3.47 r.p.s., .0323. There is more than the usual variation in these values, but using the smallest, that is, .0285, and an average frequency of 3.65 for the S2 and S4 classes, the theoretical and measured oscillations and dynamic magnifiers are shown in Fig. 42. In Fig. 43, the same information is given for several of the lighter classes, using an average frequency of 3.98.

About the best that can be said of these diagrams is that the theoretical values of the oscillations are above the measured values. We have reached the length of span in which damping of some sort, probably that from the locomotive springs, takes place, and the oscillations at or near synchronous speed are comparatively small. The three high oscillations shown in Fig. 42, are from locomotives having such small hammer blow that they did not effect the springs, but to bring them up to the common D_h of .003082, for which the diagram is made, the actual oscillations have been multiplied by a factor of from about 1.4 to 1.6. In Fig. 43, the effect of this damping is more noticeable, and at a speed of 5 r.p.s. there is an indication that the oscillations are beginning to increase in height as the second synchronous speed is approached.

For a bridge of this type and design, there was a large amount of lateral movement, which probably was caused by the poor bearing at one corner. The oscillations are usually greater in the north truss than in the south, but the larger have been plotted in all cases.



Tests-A 1124 to A-1162 July 1934
" B-877 to B-916 " "

DESIGN DATA

Date 1913 Spec. 1910
Material OH Steel
Loading E-60 E.U.L.L.
Flange Stress D.L. 3310
(Tens N Sec.) L.L. 8570
Imp 5940
Total 17820

Gross M. of I. at Center
Weight Steel per Ft. 2365
Weight Deck per Ft. 555
Total per Ft. 2920
Total for Span 408,700

COMPUTED DEFLECTION
Theoretical 100% Factor

For 1000 Lbs per Ft. Trk. 1026
For 1000 Lbs. at Center 00156
D.L. Deflection .2996
D.L. Frequency 6.32

COMPUTED FROM TESTS

Deflec. 1000 Lbs. per Ft. Trk. .0862
Deflec. 1000 Lbs. at Center .00131
Deflec D.L. .2517
Frequency D.L 6.90

$\frac{\text{Observed Deflec}}{\text{Computed Deflec}} = 0.840$

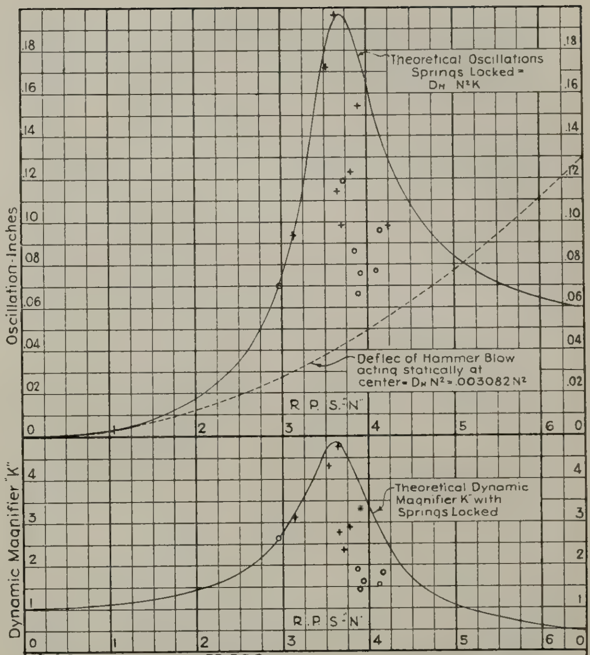
LOCOMOTIVES USED IN TESTS

Class of Engines		K5P I	K5B I	H5L I	H10B I	L2B	L2D		H10B II
Engines per Class	Big 4	2	2	1	1	4	6		1
Tests per Class		6	8	4	2	8	14		2
Class of Engines		K5	K5A	S2	S4				
Engines per Class	Erie	2	1	7	5				
Tests per Class		4	2	16	14				

SPAN 8

Bridge 23 Indianapolis
Single Track Span
140-0 Thru Truss
Riveted

Fig. 41

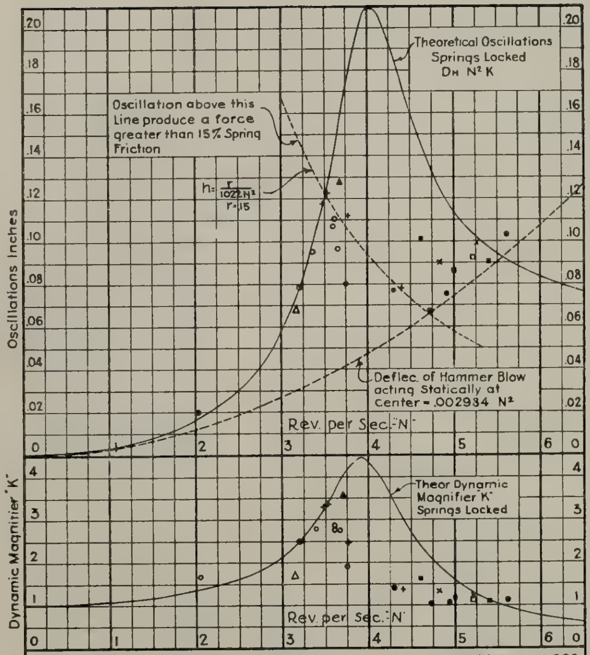


ERIE R R Type S4 ○	H.B.I R.P.S.	DH	ERIE R R. Type S2 +	H.B.I R.P.S.	DH
3390	2808	.003904	3327	1620	.002242
3389	2231	.003082	3345	1458	.001995
3396	2853	.003985	3326	1463	.001995
3403	2998	.004172	3387	2736	.003818
3400	2657	.003648	3334	2211	.003038
			3338	1527	.002120
			3325	1536	.002131

Loaded Freq. $n = 3.65$
Damp. Constant $p = .0285$
Damp. factor $\Delta = 2pn = .208$
D L Deflec. .2517 in. Freq = 6.32
Highest oscillations are plotted corrected to $D_H = .003082$

SPAN 8
SINGLE TRACK THROUGH TRUSS
RIVETED
140'-0" LONG

Fig. 42



Eng.	H.B.I R.P.S.	DH
○ - L2D	2154	.002984
+ - L2B	1844	.002574
△ - H10BI	1188	.001667
▲ - H10BII	803	.001116
● - K5BI	1660	.002253
■ - K3PI	2076	.002738

Eng (ERIE)	H.B.I R.P.S.	DH
X - K5 2924	1977	.002846
2927	2128	.003090
□ - K5A 2943	1961	.002827

Loaded Freq. $n = 3.98$
Damp. Constant $p = .0285$
Damp. Fac. $\Delta = 2pn = .227$
D.L. Defl. .2517 Freq. 6.32

Highest oscillations are plotted, corrected to $D_H = .002984$

SPAN 8
SINGLE TRACK THROUGH TRUSS
RIVETED
140-0" LONG

Fig. 43

TABLE XXII

BR. 23- INDPLS DIV SINGLE TRK RIVETED THROUGH TRUSS- 140-0" C. To C. BEARINGS Sheet 1 Span 8

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No	Locomotive H B at 1RPS	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No	Cars Kind	Stat LL Defl at Dist 'P'	Stat LL Defl Defl (ins) D	EULL (Kips)	Loaded Frequency 'n'	Speed RPS 'N'	Speed MPH	Hammer Blow Dist H (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow DaN² at Center	Dynamic Magnifier 'K'	Impact γ'	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A-1157	1	S	E	Erie-S4	3390	2808	4680	3519	51	F	1085	661	767	362	296	3695	198	054	034	159	82	331	8.69	.71	1271
B-911	·	N	·	-	-		-		·		1085	674			293	3656	19.8	090	.034	265	136	-	·	118	1318
A 1146	·	S	E	-	3389	2231	-	3519	38	-	1040	651	756	364	—	—	162	[illegible]	—	—	153	-	856	131	1318
B-899	·	N	·	·	-	-	-	·		·	1050	708			—	—	172	119	—	—	183	·	-	157	1344
A 1124	-	S	E	-	3396	2853	·	3519	64	-	1066	658	7.63	363	3.86	4824	18.3	.106	.059	1.80	161	·	865	139	1335
B-877	·	N	-			·	·		-	-		721			358	4814		111	059	188	169	-	·	146	1342
A-1147	·	S	E	·	3396	2853	-	3519	61	·	1086	.662	768	3.62	389	4862	20.3	057	060	95	8.6	·	871	.75	1277
B-901		N	·				-				108.5	.692			3.89	4861	202	085	.060	142	129	-	-	112	1314
A 1160	·	S	E	·	3403	2998		3519	62		1077	655	760	363	392	4899	191	.080	064	125	122	·	861	105	1297
B 914		N	-	·	·		·	-	·		1068	688			392	4899	182	103	064	161	157	-	-	135	1327
A 1129		S	E	-	3390	2808	·	3519	70	-	1112	652	756	364	411	5137	225	073	.066	91	112	·	8.57	96	1284
B 882		N	-		-	·	-	·		·	1078	695			410	5126	191	.098	.065	151	150	·	·	129	1317
A 1126		S	E		3400	2657	-	3519	61		104.0	654	759	363	415	5190	160	.114	.063	181	174		860	150	1341
B 879		N		·		·		·	·	-	1080	714			415	5190	200	.095	.063	1.51	145	-	-	125	1316
				Average	South	Truss		351.9			1072	.656	7.61	363			189					3.31	863		
					North	Truss					107.4	697					19.1								
A-1150	1	S	E	Erie-S2	3327	1620	4575	3519	70	F	1079	632	733	368	3.15	3933	212	056	.022	254	89	331	831	.74	1236
B-904	-	N	·	-	·		·	·			1071	682			315	39.33	20.4	.068	022	3.09	107	-	-	.89	1251
A-1140	·	S	E	-	3345	1458		3519	68	·		653	757	364	356	4448		108	025	432	164		8.59	141	1331
B-893	-	N	·	·	-		-	·				.694			3.52	4399		102	.025	408	167	·	-	1.35	1325
A-1139	·	S	E	-	3326	1463		351.9	62	·	1080	652	7.56	364	364	4549	218	092	027	341	141	-	857	121	13.09
B-892	-	N	-	·	-		·		-		1049	690			365	4562	187	.128	.027	474	196	·	·	168	13.56
A-1142		S	E	-	3327	1620	·	3519	64	·	1086	642	745	366	368	4599	219	083	030	276	129	-	844	109	1284
B-895	·	N		-				-		-	1082	675			362	4524	215	080	030	267	125	-	·	106	1281

Sheet 2 Span 8

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No	Locomotive H B at 1RPS	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No	Cars Kind	Stat LL Defl at Dist 'P'	Stat LL Defl Defl (ins) D	EULL (Kips)	Loaded Frequency 'n'	Speed RPS 'N'	Speed MPH	Hammer Blow Dist H (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow DaN² at Center	Dynamic Magnifier 'K'	Impact γ'	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A-1134	1	S	E	Erie-S2	3387	2736	4575	3519	74	F	1078	648	752	365	369	4611	196	122	052	235	188	331	852	160	1343
B 887	-	N	·	-	-		-	-		-	1075	696			369	4609	193	122	052	235	188	·	·	160	1343
A 1162	-	S	E	-	3334	2211	-	3519		-	1086	658	763	363	376	4698	203	090	042	214	136		865	118	1314
B-916	-	N	-	-	-		-	-		·	1070	706			376	4696	197	122	.042	290	185			160	1356
A 1152	-	S	E	-	3338	1527		3519			1077	655	760	363	391	4881	209	.082	.032	256	125		8.61	107	1299
B 9[illegible]	·	N	-	-	·		·	·		··	1083	679			390	4870	215	106	.032	331	162			139	1331
A-1136	-	S	E	·	3325	1563		3519		-	1044	.655	760	363	—	—	176	.068	–		104		861	90	1282
B-889	·	N	·	-	-	-	-	-			1066	688			—	—	198	063	—		96		·	83	1275
				Average S Truss			4575	3519			1076	649	753	3.65			205					331	853		
				· N Truss			4575	3519			1071	.689					201								
A-1151	1	S	E	L2D	6234	2153	3670	2271	58	F	1076	540	626	389	204	25.13	154	020	012	167	37	331	710	26	1067
B-905	·	N	-	·	-	—	-		-		1083	540			204	2512	161	.019	012	158	36			26	1067
A-1154	-	S	E	·	6235	··	·	2316	-		1074	555	6.44	386	323	3970	152	077	031	248	37	·	730	100	1161
B 908	·	N	·	·	-	·	·	·	·	·	1070	561			321	3955	148	078	031	251	139			101	1162
A-1145	·	S	E	-	6238	-	-	2041	··	-	1075	552	640	386	339	4169	153	.087	.034	256	156		726	113	1170
B-898	·	N	·	·	·	·	·	·	··	·	1084	553			339	4167	162	095	034	279	178	·		129	1186
A-1158	-	S	E	·	6238	·		2116	·	-	1073	570	661	382	360	4430	151	099	039	254	156		750	117	1198
B-912	·	N	-	·		·	·	·		-	1088	521			361	4438	166	107	039	274	205			153	1234
A-1137	·	S	E	·	6232		·	1964	·		1074	522	606	394	361	4448	152	110	039	282	211	·	686	145	1162
B-890		N	·	·	·	·		·	·		1034	544			361	4448	112	110	039	282	202		-	139	1156
A-1135	1	S	E	L2D	6233	2153	3670	2416	52	F	1068	570	661	382	366	4505	146	110	040	275	193	331	750	145	1226
B-888	-	N	··		·		-		-	·	1072	568			366	4504	150	086	040	215	154		·	106	1187

Sheet 3 Span 8

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist P	Defl (ins) D	E U L L (Kips)	Loaded Frequency n	Speed R P S N	Speed M P H	Hammer Blow Dist H (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact %	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A-1125	1	S	E	L2 D	6230	2153	367.0	237.6	49	F	1074	537	6.23	3.90	375	4613	152	080	042	190	149	331	706	105	1142
B-878	·	N		..							1064	535			3.75	4613	142	.073	.042	174	13.6		..	96	1133
				Average S	Truss		367.0				1073	.549	637	3.87			151					3.31	722		
				N	Truss		3670				107.1	.542					149								
A-1141	1	S	E	L2 B	6218	1844	3640	211.6	63	F	103.2	.497	557	400	3.47	4270	110	101	031	326	20.3	331	654	132	1117
B-894	..	N	..	..	..	..	·	·	-	·	1033	.538			349	4272	111	.100	031	323	186		..	122	1107
A-1161	..	S	E	..	6224	-	-	212.1	63	..	1034	.499	579	400	351	4315	11.2	.100	032	3.12	200	·	656	131	1118
B-915	..	N	..		-	-	-	-	..	-	1033	.528			3.51	43.20	111	106	032	3.30	20.1		·	1.32	1119
A-1130	..	S	E	-	6220	..	..	196.9	60	·	1044	.517	6.00	3.95	376	4627	12.2	.078	.036	2.17	159	-	680	108	1119
B-883	..	N	-	..	..	..	..	..	·	..	1046	552			3.76	4627	124	.097	.036	242	175	-	-	1.19	1130
B-900	..	N	E	-	6219	·	..	2316	38	..	1030	538		389	439	53.99	108	.067	.050	134	12.5				
				Average- S	Truss		364.0	2131			1037	.504	585	398			115					3.31	663		
				.. N.	Truss		3640	2131			1037	.639					115								
A-1149	1	S	E	H10B I	220	1188	334.5	1975	71	F	1044	.475	551	406	3.17	35.60	19.2	023	.017	135	48	3.31	625	30	9.86
B-903	-	N	-	..	..	..	..	·	..	·	100.9	498			316	3555	157	.027	.017	159	54	-	-	.34	990
A-1127	-	S	E	H10B II	329	803	..	2156	61	..	1008	.500	5.80	899	370	4181	148	.053	.015	353	10.6	-	658	70	1059
B-880	-	N	..	..	..	-	·	..	..	..	998	.506			3.69	4169	13.8	.048	.015	3.20	95	-	..	.63	1052
				Average-South	Truss		3345	2066			1026	.488	566	402			174					331	642		
			..	North	..		334.5	2066			100.4	.502					144						·		

Sheet 4 Span 8

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Eng No	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist P	Defl (ins) D	E U L L (Kips)	Loaded Frequency n	Speed R P S N	Speed M P H	Hammer Blow Dist H (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact %	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A 1131	1	S	E	H5-L	6028	2090	2757	1405	15	F	1030	417	484	423	083	929	158	005	002	250	12	331	548	07	886
B-884	..	N		-	..	-		-			1020	436				-	148	005	·		12	·	-	07	886
A-1153	-	S	E	-	6028	-	..	1427	7	..	1090	411	477	425	093	1040	218	.005	.003	167	12	-	540	06	877
B-907	-	N	·	-	·	-		..	·		1030	.438			092	1038	15.8	005			12	-		06	877
				Average	S Truss		2757	1416			1060	414	480	424			188					331	544		
					N· Truss		2757	1416			1025	437													
A-1156	1	S	E	Erie K5	2927	2128	3165	1920	7	P	1046	511	593	3.97	482	6792	15.5	092	.072	128	18.0	331	672	121	1124
B-910	..	N	..	-	·	-	..	..	-		105.2	496			482	6802	16.1	087	072	121	175	..	·	118	1121
A-1144	-	S	E	-	2924	1977	..	1920	7	..	1061	500	580	400	524	7388	170	090	078	115	180	·	658	118	1107
B 897	-	N	..		..	-	·	·	..		1069	495			526	7415	179	.094	079	119	190	·	·	125	1114
				Average	S Truss		3165	1920			1054	506	587	399			163					331	665		
					N Truss		3165	1920			1060	495					170								
A-1133	1	S	E	Erie K5A	2943	1961	3079	1876	7	P	985	468	543	408	523	7377	94	045	077	.59	92	331	615	57	1003
B-886	-	N	-		..	..	..		-		1005	.505			524	7388	114	087	077	113	172		·	106	1052
A-1138	1	S	E	K5B I	6508	1560	297.5	2190	9	P	1077	.465	5.39	409	429	6053	185	.057	.041	139	123	331	611	.75	1017
B-891	-	N	..	..	..	·	..			·	1043	512			429	6053	151	058	.041	141	113	-	..	.69	1011
A-1159	-	S	E	..	6508	-	·	2190	9	·	1090	497	577	400	473	6669	198	.050	.050	100	101	·	654	66	1051
B-913	..	N	..	..	..	..	·		·	..	1092	516			472	6650	20.0	050	050	100	91	·		.60	1045
A 1148	·	S	E	·	6512		·	2106	9		1096	485	563	403	494	6962	204	.057	055	104	118		638	75	1044
B-902	·	N	..	·	·	..	·	·	..	·	1100	518			493	6952	20.8	.057	055	104	110	·	..	70	1039

Sheet 5 Span 8

Test				Locomotive					Cars		Stat. Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D	E U L L (Kips)	Loaded Frequency n	R.P.S. "N"	M P H	Dist "H" (Ft)	Oscil (ins)	Stat Defl H Blow $D_h N^2$ at Center	Dynamic Magnifier K	Impact I	DL	LL	Imp	Total
A-1128	1	S	E	K5B I	6508	1560	2975	2063	8	P	1095	457	530	411	561	7915	203	070	071	.99	153	331	601	93	1025
B-881		N	..	·	..	-	..	-	-	·	1065	518			561	7915	173	078	.071	1.10	151	..	·	.91	1023
				Average	S-Truss		2975	2137			1089	476	5.52	406			197					3.31	6.26		
				-	N Truss		2975	2137			107.5	.516					183								
A-1143	1	S	E	K3P I	6478	2076	280.2	1220	5	P	993	510	592	397	461	65.02	107	071	058	123	139	3.31	671	93	1095
B-896	..	N	.	..	-	..	..	·	-	-	1008	.525			461	6506	122	093	058	160	17.8	-	-	119	1121
A-1155	-	S	E	-	6476	..	..	1230	3	-	1007	.512	594	3.96	500	7053	121	.070	.069	101	137	·	673	.92	1096
B-909	-	N	-	-	·	-	..	..	..	..	1010	.517			5.00	70.53	124	079	.069	114	153	-	-	1.03	1107
A-1132	-	S	E	-	6476	..	-	131.7	3	-	1013	.527	6.11	3.93	5.40	7618	12.7	.072	.080	90	137	-	693	.95	11.19
B-885	-	N	..	-	-	..	-	-	·	..	1036	.528			5.41	7630	150	.083	.080	1.04	157	-	·	109	1133
				Average	S-Truss		280.2	1256			1004	516	599	395			11.8					3.31	6.79		
				-	N-Truss		2802	125.6			1018	.523					132								

NOTE-There was play under N W bearing, For deflections, frequencies E.U. L L etc use S.Truss deflections, The impact percentages shown for the North truss are computed by using the oscillation for that truss, and the static deflection of the South truss.

SPAN NO. 9

A single track riveted through truss, 138 ft. long and 28 ft. deep, center to center of chords. See Fig. 44.

This truss is very similar in all respects to Span No. 8. The bridge is located in a town which restricts the speed of all trains, and it was difficult to get many tests at the higher speeds. Only the tests of the second series are included, as those taken earlier are of no especial interest, as the speeds were too low.

It will be noticed that the average deflection of the south truss was, for nearly all classes of engines, about .02 inch more than that of the north truss. The substructure was of recent construction and in excellent condition, and there was no noticeable movement under any of the bearings. It may be, however, that there was enough friction in the expansion bearing of the north truss to check the deflection somewhat. Another bit of evidence favoring this conclusion, is that many of the oscillations, especially at the lower speeds, are smaller in the north truss, which would be accounted for by friction damping. It was decided to use the deflections as recorded in the north truss, as these, being smaller, would give smaller values for D_h, and higher values for the dynamic magnifier, and a smaller damping factor.

It was possible to measure the deflection under a string of cars of known weight placed on the bridge. The spacing of the axles was determined by measurements and under this quiescent load the deflection factor was found to be .798. Using the average deflection and loading of the J1-D locomotives, this factor was found to be .797. Using the south truss deflection these factors are .810 and .820, which are more in line with other spans of this type, but the difference is slight.

Using a value of .798, the dead load deflection is .2352 inch; the dead frequency is 7.13, and the hammer-blow deflections, D_h, are as follows:

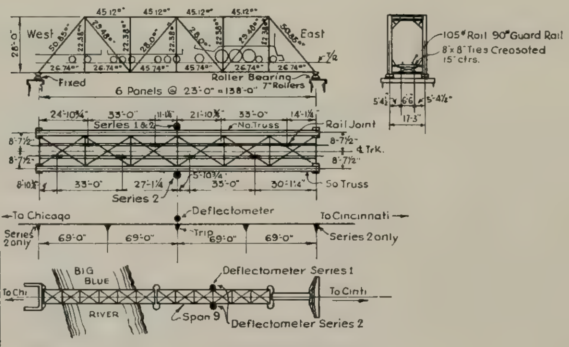
Class of Locomotive	D_h (Inches)	*Class of Locomotive*	D_h (Inches)
J1-D	.001921	H10-A—Type I	.001397
K5-A; K5-B—I; K5-B—II	.001767	" II	.001445
K3-Q—I	.001840	H10-B— " I	.001278
L2-D	.002467	H 7-E— " V	.002720
L2-B	.002050	H6-A	.002329
L2-C	.002050	H5-O—II; H5-LA—III	.002270

From Test A-857, Class J1-D locomotive running at 3.86 r.p.s., oscillation .116 inch, and frequency, *n*, of 4.15, we obtain a value for Δ, of .263, giving a value for the damping constant, *p*, of .0317.

From Test B-600, Class J1-D locomotive, $N = 3.94$; $n = 4.21$; the oscillation is .113 inch, which gives for the damping constant, a value of .0292.

From Test A-856, Class L2-C locomotive, $N = 4.27$; $n = 4.04$; the oscillation is .125 and we find that $p = .032$.

Assuming an average value of .030, and an average frequency of 4.05, the theoretical values of the oscillations and dynamic magnifiers have been computed and are shown in Fig. 45. The actual values, at or near synchronous speeds, agree very well with the computed values. For some reason there is no indication of damping at these higher speeds, while in Span No. 8, which is very similar, the effect of damping is marked.



Series 1-Tests A-60 to 85 July 1931
Series 2 { Tests A 818 to 864 June 1933
" B 564 to 609 " "

NOTE:- Tests of Series 1 were at such low speeds that they have not been included.

DESIGN DATA

Date 1916 Spec. 1910
Material O H Steel
Loading E-60 E.U.L.L. 7610
Flange Stress D.L. 3310
(Tens. N. Sec.) L.L. 8640
Imp. 6000
Tot. 17950
Gross M. of I. at Center
Weight Steel per Ft. 2440
Weight Deck per Ft. 450
Total per Ft. 2890
Total for Span 398300

COMPUTED DEFLECTION
Theoretical 100% Factor

For 1000 Lbs. per Ft. Trk. .1035"
For 1000 Lbs. at Center .00156"
D.L. Deflection .2995
D.L. Frequency 6.33

COMPUTED FROM TESTS

Deflec. 1000 Lbs. per Ft. Trk. .0814"
Deflec. 1000 Lbs. at Center .00123"
Deflec. D.L. .2353
Frequency D.L. 7.13
$\frac{\text{Observed Defl.}}{\text{Computed Defl.}} = .786$

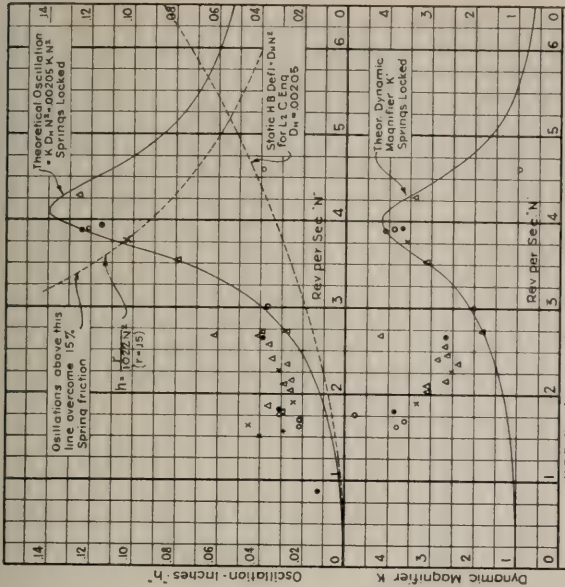
LOCOMOTIVES USED IN TESTS

Class of Engines				K5B (I)	K5B II	K3Q	K5A	J1D		H6A
Engines per class				2	2	1	1	3		1
Tests per Class				4	4	8	2	14		2
Class of Engines		H5-O II		H10-A (I)	L2B	L2D	L2C		H10A II	H5LA III
Engines per class		2		1	2	1	6		1	1
Tests per Class		6		6	8	2	17		2	6

SPAN 9

Bridge 413 Chicago Div
Center Span Single Main
138-0' Thru Truss
Riveted

Fig. 44



Symbol	Eng Class	H.B.Defl 1·RPS D_H	Aver Loaded Freq 'n'	Damp Factor $\Delta = 2pn$
○	J1D	.00192	4.15	.249
×	K5A	.00177	4.18	.251
×	K5B	.00177	4.18	.251
△	L2B	.00205	4.14	.248
△	L2C	.00205	4.04	.242
+	L2D	.00247	4.18	.251
●	K3Q	.00184	4.28	.255

D L. Deflec. 0.235"
D L. Freq. 7.13
Damp. Constant p .030

NOTE:-The maximum oscillation are used and in plotting are corrected to L2 C-Engines
D_H - .00205
Δ = .243
n = 4.05

SPAN 9
SINGLE TRACK THROUGH TRUSS
RIVETED
138'-0" C. to C Bearings 28'-0" Deep

Fig. 45

TABLE XXIII
SINGLE TRACK RIVETED THROUGH TRUSS - 138'-0" c. to c - 28 ft. DEEP

Sheet 1 Span 9

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat. L.L. Defl.		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl. H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B. at 1 RPS.	Weight (Kips) Eng	Weight (Kips) Tender	No.	Kind	at Dist. 'P'	Defl. (ins) 'D'			R.P.S. 'N'	M.P.H.	Dist 'H' (Ft.)	Oscil (ins)				D.L.	L.L.	Imp	Total
A 835	2	N	W	J1D	6604	1691	3530	266.4	14	P	1046	.485	5.96	4.08	1.66	2336	16.4	.020	.0055	3.77	41	331	6.82	.28	10.41
B 580	-	S	-	-	-	-	-	-	-	-	1060	507			167	2347	178	019	.0053	3.58	4.0	-	-	28	1041
A 862	-	N	W	-	6605	-	-	223.0	14	-	1080	.479	5.88	4.10	1.69	23.80	19.8	.018	.0055	3.27	39	-	6.73	26	10.30
B 607	-	S	-	-	-	-	-	-	-	-	1047	.494			1.68	23.70	16.5	.020	.0055	3.63	4.2	-	-	.28	10.32
A 838	-	N	W	-	6604	-	-	283.1	6	-	1080	.504	6.19	4.03	176	2478	19.8	.020	.0060	3.33	3.9	-	7.08	.28	10.67
B 583	-	S	-	-	-	-	-	-	-	-	107.0	.504			1.76	2478	18.8	.029	.0060	4.83	5.7	-	-	.40	10.79
A 826	-	N	E	-	6604	-	-	173.2	10	-	1030	467	5.73	4.13	3.00	42.53	14.8	.035	.0172	2.03	7.5	-	6.53	.49	10.33
B 571	-	S	-	-	-	-	-			-	1010	470			301	4238	12.8	.031	.0172	1.80	6.6	-	-	43	10.27
A-857	-	N	E	-	6601	-	-	272.4	13	-	1087	.470	5.78	4.13	3.85	5429	20.5	.116	.0285	4.07	24.7	-	6.59	1.64	11.55
B-602	-	S	-	-	-	-	-	-	-	-	1100	.457			3.88	5471	21.8	103	.0289	3.57	21.9	-	-	1.44	11.35
A 855	-	N	-	-	6604	-	-	148.7	11	-	1057	.442	5.45	4.21	3.91	5514	17.5	.113	.0293	3.86	25.5	-	6.21	1.68	11.21
B-600	-	S	-	-	-	-	-	-	-	-	1081	.471			3.96	5609	19.9	.113	.0301	3.75	25.5	-	-	1.68	11.21
A 827	-	N	-	-	6605	-	-	200.1	14	-	1081	467	5.73	4.13	4.57	6447	19.9	.036	.0401	90	7.7	-	6.53	.50	10.34
B-572	-	S	-	-	-	-	-	-	-		1054	494			464	6543	172	.035	.0413	84	7.5	-	-	50	10.34
		Aver	E	Bound-	N Truss		3530	1986			1064	.461	5.67	4.15			18.2					3.31	6.46		
					S -		-	-			1061	473					17.9					-	-		
			W	..	N -		353.0	2575			1069	.489	6.01	4.07			18.7					3.31	6.88		
					S -		-	-			1059	502					17.7					..	-		
A-849	2	N	W	K5B I	6513	1660	2975	242.3	8	P	112.0	.448	5.51	4.19	1.51	21.35	23.8	.032	.0040	8.00	71	3.31	6.28	.44	10.03
B-594	-	S	-	..	-	-	..	-	.	-	1120	473			1.52	21.38	23.8	035	0040	8.75	78	-	-	.49	10.08
A-819	..	N	W	K5B II	6521	..	3020	2484	9	-	1070	462	5.78	4.14	1.63	2300	18.8	037	0047	7.87	80	-	6.38	.51	10.20
B 564	-	S	-	-	-	..	-	..	-	..	1080	.482			1.63	2300	19.8	039	.0047	8.29	81	-	-	52	10.21
A 844	-	N	W	K5A	6527	1558	301.0	1836	6	-	102.0	473	5.82	4.12	1.89	2669	13.8	021	0064	3.28	4.4	-	6.63	29	10.23
B 589		S	..	-	.	-	-	-		.	104.0	480			1.90	2674	15.8	.019	0064	2.97	4.0	-	-	27	10.21

Sheet 2 Span 9

Test				Locomotive					Cars		Stat. L.L. Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net. Sec.			
No.	Series	Girder	Direc. of Movement	Class	Eng. No.	H. B at 1 R.P.S.	Weight (Kips) Eng	Weight (Kips) Tender	No.	Kind	at Dist. "P"	Defl. (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)	Stat. Defl. H. Blow D_0N^2 at Center	Dynamic Magnifier "K"	Impact %	D.L.	L.L.	Imp.	Total
A-839	2	N	E	K5BI	6508	1560	2975		7	P	107.2	.454	5.58	4.18	2.26	31.92	19.0	.027	.0090	3.00	5.8	3.31	6.36	.37	10.04
B-584	"	S	"	-	"	"	"		"	"	108.0	.452			2.26	31.83	19.8	.021	.0090	2.33	4.6	"	"	.29	9.96
A-847	"	N	E	K5BII	6516	"	"	246.3	12	"	105.6	.455	5.60	4.18	3.77	53.16	17.4	.088	.0251	3.51	19.3	"	6.38	1.23	10.92
B-592	"	S	"	"	"	"	"	"	"	"	105.1	.452			3.79	53.41	16.9	.076	.0254	3.00	16.7	"	"	1.07	10.76
			Aver.	E. Bound-	N.	Truss	297.5	246.3			106.4	.454	5.58	4.18			18.2					3.31	6.36		
					S	"	"	"			106.6	.452					18.4					"	"		
				W Bound	N	"	300.2	224.8			107.0	.461	5.67	4.15			18.8					3.31	6.46		
					S	"	"	"			108.0	.478					19.8					"	"		
A-831	2	N	E	K3Q	6487	1645	295.5	184.1	3	P	106.4	.427	5.25	4.26	.88	12.44	18.8	.012	.0014	8.54	2.8	3.31	5.99	.17	9.47
B-576	"	S	"	"	"	"	"	"	"	"	108.0	.441			.88	12.35	20.4	.011	.0014	7.86	2.6	"	"	.16	9.46
A-851	"	N	W	-	6487	"	"	186.6	10	"	107.7	.432	5.31	4.26	1.80	22.17	20.1	.027	.0070	3.86	6.2	"	6.05	.41	9.77
B-596	"	S	-	"	"	"	-	-	"	"	103.4	.438			1.80	22.21	15.8	.020	.0070	2.86	4.6	"	-	.28	9.64
A-821	"	N	W	"	6487	"	"	186.6		"	108.2	.427	5.25	4.26	2.68	37.82	20.6	.035	.0132	2.65	8.2	"	5.99	.49	9.79
B-566	"	S	"	"	"	"	"	"		"	104.5	.429			2.64	37.82	16.9	.029	.0123	2.36	6.8	"	"	.41	9.71
A-860	"	N	E	"	6487	"	"	186.6	6	"	106.0	.427	5.25	4.26	3.93	55.41	18.4	.103	.0284	3.63	24.1	"	5.99	1.44	10.74
B-605	"	S	"	"	"	"	"	"	"	"	104.8	.428			3.93	55.41	16.2	.100	.0284	3.52	23.4	"	"	1.40	10.70
			Aver-	E Bound-	N. Truss		295.5	185.4			106.2	.427	5.25	4.26			18.6					3.31	5.99		
					S "		"	"			106.4	.435					18.8					"	"		
				W Bound	N. Truss		295.5	186.6			108.0	.429	5.28	4.26			20.4					3.31	6.02		
					S "		"	"			104.0	.434					16.4					"	"		
A-834	2	N	W	L2D	6225	2153	367.0	272.4	54	F	109.0	.455	5.60	4.18	1.56	19.24	18.8	.032	.0060	5.33	7.0	3.31	6.38	.45	10.14
B-579	-	S.	"	-	"	-	"	"	"	"	110.0	.485			1.57	19.26	19.8	.035	.0060	5.83	7.7	-	"	.49	10.18

Sheet 3 Span 9

Test				Locomotive					Cars		Stat. L.L. Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net. Sec.			
No.	Series	Girder	Direc. of Movement	Class	Eng. No.	H. B at 1 R.P.S.	Weight (Kips) Eng	Weight (Kips) Tender	No.	Kind	at Dist. "P"	Defl. (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)	Stat. Defl. H. Blow D_0N^2 at Center	Dynamic Magnifier "K"	Impact %	D.L.	L.L.	Imp.	Total
A-842	2	N	E	L2C	2887	1854	365.0	270.8	18	F	112.5	.509	6.26	4.02	1.79	22.02	22.3	.030	.0065	4.61	5.9	3.31	7.14	.42	10.87
B-587	.	S	.	.	"	-	"	"	.	.	107.4	.522			1.80	22.10	17.2	.022	.0065	3.38	4.3	.	"	.31	10.76
A-820	-	N	E	-	2879	"	.	270.8	54	.	111.2	.500	6.15	4.03	1.84	22.65	21.0	.036	.0069	5.22	7.2	-	7.01	.50	10.84
B-565	.	S	"	-	"	"	"	.	"	.	107.2	.501			1.84	22.65	17.0	.026	.0069	3.74	5.2	"	.	.36	10.70
A-840	-	N	W	-	2879	"	.	269.3	55	.	108.4	.477	5.87	4.10	2.04	25.06	18.2	.025	.0085	2.99	5.2	"	6.69	.35	10.35
B-585	-	S	.	"	.	"	.	.	"	-	110.0	.496			2.04	25.06	19.8	.026	.0085	3.06	5.4	.	"	.36	10.36
A-824	-	N	W	"	2882	"	"	279.6	75	"	109.0	.487	5.99	4.08	2.15	26.45	18.8	.025	.0095	2.63	5.1	-	6.83	.35	10.49
A-828	-	N	E	.	2859	"	.	261.7	40	.	109.0	.498	6.12	4.04	2.36	29.03	18.8	.027	.0114	2.36	5.5	"	6.98	.38	10.67
B-573	-	S	.	.	"	.	"	-	"	"	110.0	.513			2.35	28.78	19.8	.026	.0114	2.28	5.1	"	.	.35	10.64
A-854	.	N	W	"	2859	"	"	270.8	71	"	106.0	.476	5.85	4.10	2.41	29.64	15.8	.027	.0119	2.27	5.7	.	6.67	.38	10.36
B-599	-	S	-	"	-	.	"	.	"	"	107.5	.502			2.42	29.78	17.3	.034	.0119	2.85	7.1	"	.	.47	10.45
A-843	.	N	W	.	2859	"	"	279.6	40	"	109.2	.492	6.05	4.05	2.67	32.90	19.0	.061	.0146	4.18	12.4	.	6.90	.85	11.06
B-588	.	S	.	.	"	.	"	.	-	"	109.6	.480			2.67	32.84	19.4	.040	.0146	2.74	8.1	"	"	.56	10.77
A-850	-	N	E	"	2864	.	"	261.1	54	"	109.6	.490	6.03	4.06	2.71	33.33	19.4	.035	.0150	2.33	7.1	"	6.87	.49	10.67
B-595	-	S	.	.	"	"	"	"	.	"	110.0	.506			2.71	33.37	19.8	.039	.0150	2.60	8.0	"	.	.55	10.73
A-856	"	N	E	.	2854	"	"	256.3	42	"	110.4	.499	6.04	4.04	4.27	52.51	20.2	.125	.0374	3.34	25.0	.	6.89	1.72	11.92
B-601	"	S	.	"	"	"	"	"	"	-	111.0	.525			4.28	52.61	20.8	.101	.0374	2.70	20.3	"	"	1.40	11.60
			Aver-	E. Bound	N Truss		365.0	264.1			110.5	.499	6.04	4.04			20.3					3.31	6.89		
			"	. .	S "		"	"			109.1	.513					18.9					"	"		
			"	W Bound	N Truss		365.0	274.8			108.1	.483	5.94	4.08			17.9					3.31	6.77		
			"	" "	S "		"				109.0	.493					18.8					"	"		

Sheet 4 Span 9

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_h N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R.P.S. "N"	M.P.H.	Dist "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-837	2	N	E	L2 B	6210	1844	3640	2531	69	F	1074	485	597	408	211	2591	172	028	.0908	308	58	331	680	39	1052
B-582	·	S	·	··	·	·	-	·	·	·	1103	510			210	2586	201	024	0908	264	50	-	··	34	1047
A-861	·	N	W	··	6210	·	-	2316	73	·	1056	447	550	414	255	3140	154	030	0133	225	67	·	627	42	1000
B-606	·	S	·	·	·	··	·	··	·	·	1050	463			254	3119	148	035	0133	263	78	-	·	.49	1007
A-825	-	N	W	·	6213	-	··	2425	41	·	1064	458	563	416	271	3329	162	025	0150	167	55	-	642	35	1008
B-570	-	S	-	-	··	-	-	··	·	-	1070	.474			271	3331	168	027	0150	180	59	-	·	38	1011
A 832	·	N	E	-	6213	-	·	2434	57	·	1069	442	544	421	353	4344	167	078	.0255	306	176	·	620	109	1060
B-577	·	S	··	-	·	·	·	··	··		1038	489			354	4354	136	.077	.0256	301	174	·	··	108	1059
			Aver	E Bound-	N Truss		3640	2482			1071	.464	571	414			169					331	651		
					S		·	·			1070	499					168					··			
				W Bound	N Truss		3640	2370			1060	453	557	418			158					331	635		
					S	··	··	··			1060	475					158					-			
A-822	2	N	E	H10A I	20	1270	3350	2341	53	F	1010	455	557	418	165	1852	145	010	0038	263	22	331	635	14	980
B 567	·	S	·	-	·	·	-	-	-	-	103.6	477			170	1908	171	015	0040	375	33	-		21	987
A 853	·	N	E	··	20	-	-	2341	37	·	1026	.457	562	417	170	1912	161	.022	0040	182	48	·	641	31	1003
B-598	-	S	-	·	-	-	·	-	·	·	1032	475			170	1913	167	014	0040	350	36			23	995
A-846	·	N	W	·	20	·	·	2340	70	··	1019	455	560	417	194	2179	154	036	0053	679	79		638	50	1019
B 591	·	S	-	·		-	-	-	·	-	1030	478			193	2172	165	.017	0052	327	39	-		25	994
A-823	·	N	E	H10A II	148	1390	-	2388	44	·	1030	460	565	414	225	2526	165	.020	.0071	282	43	·	644	28	1003
B-568	·	S	·	-	·	·	-	·	··	-	1010	472			224	2521	145	.017	0070	243	37		··	24	999
			Aver	E. Bound-	N Truss			2357			1022	457	562	417			157					331	641		
					S	-		··			1026	475					161					··			
				W Bound	N	·		2340			1019	455	560	417			154					331	638		
					S	·					1030	478					165								

Sheet 5 Span 9

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_h N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R.P.S. "N"	M.P.H.	Dist "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-818	2	N	E	H10B-I	232	1188	3345	234.1	–	F	1002	468	600	4.13	1.29	1452	162	.010	0022	454	2.1	331	6.84	14	1029
A-863	-	N	W	·	215	·	··	2.96	61	F	990	415	5.10	431	1.84	2063	150	019	.0044	432	46	-	581	27	939
B-608	-	S	·	·	··	-	··	·	-	-	982	425			184	2064	142	.017	.0044	399	4.1	·	··	.24	936
A-852	-	N	E	··	217	··	··	229.6	54	F	990	450	554	418	2.50	2812	150	.028	.0081	345	62	·	631	39	1001
B-597	·	S	-	·	··	-		-	·	·	1012	468			250	2807	17.2	.016	.0081	199	35	-	-	22	984
A-848	·	N	E	-	215	-	··	2302	1	F	1010	460	565	414	293	3289	170	032	.0111	288	70	-	644	45	1020
B-593		S	-	-	-	-	·	··	·	-	1033	.480			294	3308	193	.010	.0112	.90	22	·	-	14	989
			Aver	E.Bound-	N Truss		3345	2313			1001	459	5.64	414			161					3.31	643		
					S-	-	·	·			1012	474					172					·	·		
				W Bound	N	·	3345	2296			990	415	5.10	431			150					331	581		
					S	·	··	·			982	425					142					-	··		
A-830	2	N	E	H7E V	6159	2455	3431	2278	-	F	1010	.452	556	418	2.34	2629	145	.031	.0148	209	68	331	634	43	1008
B-575	·	S	-	··	··	··	-	··	··	·	103.8	.471			2.35	2644	172	.021	0149	141	46	··	-	.29	994
A 841	2	N	W	H6A	6112	2140	2908	1588	46	F	1012	390	480	438	252	2837	166	030	0146	205	77	331	547	42	920
B-586		S	·	·	·	··	··	·	-	··	1006	421			252	2837	160	.035	0146	240	92	-	·	50	928
A-858	·	N	E	-	6112	··	-	1550	26	F	1018	372	458	444	377	4240	152	060	.0327	183	161	-	522	84	937
B-603	·	S	-	·	··	·	-	-	-	-	990	.402			3.77	4234	144	060	.0327	183	161	··	·	84	937
			Aver	E Bound-	N Truss		2908	1550			1018	.372	458	444			172					331	5.22		
					S	-	·	·			990	402					144					·			
				W Bound	N Truss		2908	1588			1012	.390	480	438			166					331	547		
					S	·	-	··			100.6	421					160								

Sheet 6 Span 9

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat Defl H Blow $D_h N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L	L L	Imp.	Total
A-845	2	N	W	H5O II	6055	2090	275.3	129.0	1	F	115.4	.382	4.70	4.41	1.40	15.78	29.4	.007	.0045	1.55	1.8	3.31	5.35	.10	8.96
B-590	-	S	..	..	-	•	-	..	-	-	114.2	.382			1.41	15.80	28.2	.007	.0046	1.54	1.8	•	..	.10	8.96
A-829	..	N	E	-	6055	-	..		8	-	105.8	.432	5.31	4.26	1.55	17.40	19.8	.017	.0055	3.09	3.9	-	6.05	.23	9.59
B-574	..	S	..	-	..	-	..		-	-	111.2	.437			1.54	17.34	25.2	.005	.0054	1.00	1.2	-	..	.07	9.43
A-859	..	N	E	..	6704	•	-	121.9	4	-	100.0	.343	4.22	4.55	2.49	27.99	14.0	.027	.0142	1.89	7.8	•	4.81	.37	8.49
B-604	-	S	-	..	..	-	..	..	..	-	98.2	.382			2.48	27.93	12.2	.025	.0141	1.77	7.3	-	..	.35	8.45
				Aver E. Bound	N.	Truss		125.8			102.9	.387	4.76	4.40			16.9					3.31	5.43		
					S	..		..			104.7	.409					18.7					..	..		
				W Bound	N.	Truss		129.0			115.4	.382	4.70	4.41			19.4					3.31	5.35		
					S	..		..			114.2	.382					18.2					..	..		
A-833	2	N	W	H5LA-III	6141	2090	277.8	124.9	7	F	97.6	.377	4.64	4.43	1.67	18.76	11.6	.009	.0064	1.41	2.4	3.31	5.29	.13	8.73
B-578	-	S	-	-	..	..	..	..	-	-	100.5	.397			1.67	18.76	14.5	.005	.0064	.79	1.2	-	-	.07	8.67
A-864	..	N	W	..	6141	-	..	142.3	10	..	95.8	.370	4.55	4.44	1.69	18.99	9.8	.010	.0066	1.33	2.7	-	5.19	.14	8.64
B-609	-	S	-	-	-	-	-	-	-	-	101.3	.372			1.70	19.07	15.3	.007	.0066	1.06	1.9	-	..	.10	8.60
A-836	..	N	E	..	6141	-	-	165.5	5	-	98.4	.370	4.55	4.44	1.92	21.61	12.4	.017	.0085	2.00	4.6	-	5.19	.24	8.74
B-581	-	S	..	..	..	..	..	..	..	..	99.4	.372			1.93	21.67	13.4	.010	.0085	1.17	2.7	..		.14	8.64
				Aver E Bound	N. Truss		277.8	165.5			98.4	.370	4.55	4.44			12.4					3.31			
					S	..	-	-			99.4	.372					13.4					..			
				W Bound	N	-	277.8	133.6			96.7	.373	4.60	4.43			10.7					3.31			
					S	-	..	-			100.9	.384					14.9					-			
				NOTE:- For Equivalent uniform Live Loads, Frequencies, Impact and Stresses																					
				use deflections for North Truss.																					

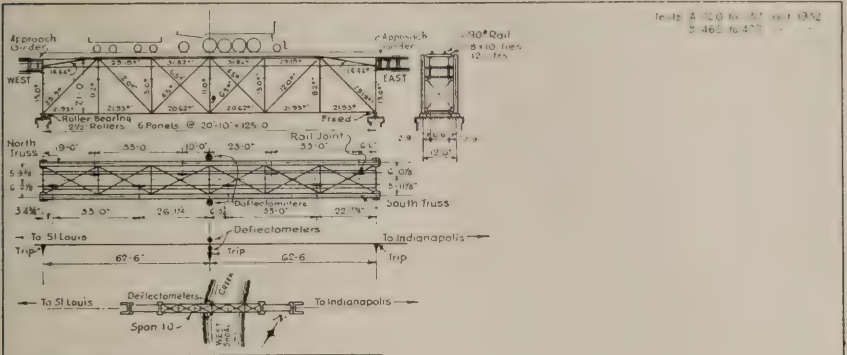
SPAN NO. 10

A single track pin connected deck truss, 125 ft. long, and 21 ft. deep, center to center of chords. See Fig. 46.

This span is old and of light design. The stringers rest on the floor beams, so that we would expect the floor system to take a smaller proportion of the chord stress than would be the case if the stringers had been framed into the floor beams. The expansion rollers are small, and were badly rusted, and there was no indication of movement under the passage of the live load, even though the deflection was almost 1 inch. There was, however, a noticeable vibration in the stone pier at the east end, and it is quite possible that it also moved under the chord elongation. Otherwise the bridge was in good condition.

The span was tested with a single engine, which took water after Tests A-725 and B-465. For the subsequent tests, the average deflection, of the south truss was .893 inch, and of the north truss, 1.035 inches. The theoretical deflection, under this loading, is 1.0076 inches, giving a deflection factor of .886 for the south truss, and 1.026 for the north. There was undoubtedly some pier settlement under the north truss, and the deflection of the south truss was probably affected by lack of expansion. In the spans previously considered, the deflection factor has ranged from .79 to .84, but owing to the construction of this bridge we would expect to find a larger value for this factor. If we assume an average, or say .95, the error cannot be more than 2 or 3 per cent, either way. The adjusted deflections then become, .956 inch for the south, and .952 inch for the north truss.

The calculated dead load deflection is .3439 inch; the unloaded frequency is 5.91, and the hammer blow deflection D_h is .00646 inch.



DESIGN DATA

Date 1894 Spec. 1893
Material Soft Steel
Loading E-57 E.U.L.L. 4160
Flange Stress D.L. 3680
(Tens. N. Sec.) L.L. 9400
Imp. 700
Total 13780
Gross M. of I. at Center
Weight Steel per Ft. 1355
Weight Deck per Ft. 480
Total per Ft. 1835
Total for Span 229500

COMPUTED DEFLECTION
Theoretical 100% Factor

For 1000 Lbs. per Ft. Trk. 1973
For 1000 Lbs. at Center .00371
D.L. Deflection .3620
D.L. Frequency 5.76

COMPUTED FROM TESTS

Deflec. 1000 Lbs. per Ft. Trk. 1874
Deflec. 1000 Lbs. at Center .00352
Deflec. D.L. .3439
Frequency D.L. 5.91

$\frac{\text{Observed Defl.}}{\text{Computed Defl}} = .95$

LOCOMOTIVES USED IN TESTS

Class of Engines										
Engines per class										
Tests per class										
Class of Engines	HSL (I)									
Engines per class	1									
Tests per class	34									

SPAN 10

Bridge 409 St Louis Div
Center Span Single Track
125 Deck Truss
Pin Connected

Fig. 46

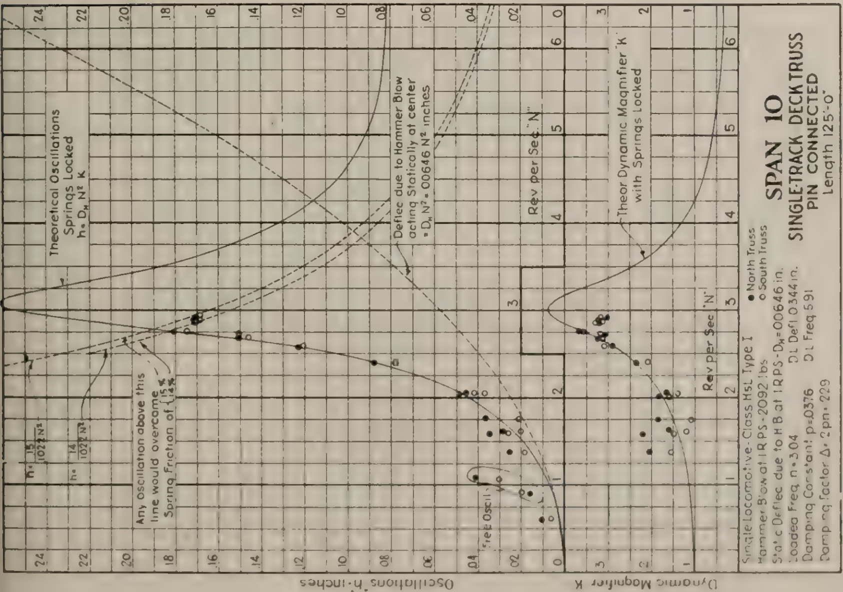


Fig. 47

TABLE XXIV

SINGLE TRACK PIN CONNECTED DECK TRUSS - LENGTH-125'-0" DEPTH 25'-0"

Sheet 1 Span 10

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L.L. Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec			
No.	Series			Class	Eng No.	H.B. at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist. "P"	Defl. (ins) "D"			R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)				D.L.	L.L.	Imp	Total
A-720	1	S	W	H5L-I	6000	2092	275.7	110.0	No	ne	92.0	.860	4.59	3.15	.60	7.15	12.6	.006	.0023	2.61	0.7	3.68	9.18	06	12.92
B 460	"	N	"	"	"	"	"	"	"	-	91.9	.998	5.33	2.99	.60	7.26	12.6	010	.0023	4.35	1.0	"	10.66	.10	14.44
A-722	"	S	W	"	6000	"	"	"	"	"	89.0	.845	4.51	3.18	.90	10.13	9.6	Free .020	.0052	3.85	2.4	"	9.02	.21	12.91
B-462	"	N	"	"	"	"	"	"	"	-	94.5	.999	5.33	2.99	.91	10.24	15.6	Free .016	.0054	2.96	1.6	"	10.66	.17	14.51
A-721	"	S	W	"	6000	"	"	"	"	"	88.7	.846	4.52	3.18	1.07	12.03	9.3	Free .030	.0074	4.05	3.5	"	9.04	.32	13.04
B-461	"	N	"	"	"	"	"	"	"	"	86.0	1.001	5.35	2.99	1.06	11.91	6.6	Free .041	.0073	5.61	4.0	"	10.70	.43	14.81
A-723	"	S	W	"	6000	"	"	"	-	"	89.4	.854	4.56	3.17	1.38	15.51	10.0	.019	.0123	1.54	2.2	"	9.12	.20	13.00
B-463	"	N	"	"	"	"	"	"	"	-	88.3	1.001	5.35	2.99	1.38	15.51	8.9	.025	.0123	2.03	2.5	"	10.70	.27	14.65
A-725	"	S	W	"	6000	"	"	"	"	-	90.8	.852	4.55	3.17	1.57	17.67	11.4	.016	.0159	1.00	1.9	"	9.10	.17	12.95
B-465	"	N	"	"	"	"	"	"	"	-	89.5	1.004	5.36	2.98	1.57	17.67	10.1	.035	.0159	2.20	3.5	"	10.72	.38	14.78
B-724	"	S	W	"	6000	"	"	"	-	"	88.6	.844	4.50	3.18	1.60	18.00	9.2	.020	.0165	1.21	2.4	"	9.00	.22	12.90
B-464	"	N	"	"	"	"	"	"	"	-	88.9	1.006	5.37	2.98	1.60	18.00	9.5	.026	.0165	1.58	2.6	"	10.74	.28	14.70
A-727	"	S	W	"	6000	"	275.7	136.0	"	-	92.7	.873	4.66	3.14	1.74	19.57	13.3	.021	.0196	1.07	2.4	3.68	9.32	.22	13.22
B-467	"	N	"	"	"	"	"	"	"	-	91.0	1.045	5.58	2.93	1.76	19.79	11.6	.037	.0200	1.85	3.5	"	11.16	.39	15.23
A-729	"	S	W	"	6000	"	"	"	"	-	91.3	.891	4.76	3.11	2.01	22.60	11.9	.042	.0261	1.61	4.7	"	9.52	.45	13.65
B-469	"	N	"	"	"	"	"	"	"	-	91.2	1.031	5.51	2.95	2.03	22.82	11.8	.049	.0266	1.84	4.8	"	11.02	.53	15.23
A-728	"	S	W	"	6000	"	"	"	"	"	90.7	.891	4.76	3.11	2.03	22.82	11.3	.037	.0266	1.39	4.1	"	9.52	.39	13.59
B-468	"	N	"	"	"	"	"	"	-	-	89.3	1.031	5.51	2.95	2.04	22.95	9.9	.045	.0269	1.67	4.4	"	11.02	.48	15.18
A-730	"	S	W	"	6000	"	"	"	"	-	91.3	.886	4.73	3.11	2.40	27.12	11.9	.078	.0372	2.09	8.8	"	9.46	.83	14.97
B-470	"	N	"	"	"	"	"	"	"	-	89.2	1.026	5.48	2.96	2.39	27.01	9.8	.088	.0369	2.38	8.6	"	10.96	.94	15.58
A-731	"	S	W	"	6000	"	"	"	"	"	89.9	.903	4.85	3.10	2.58	29.01	10.5	.121	.0430	2.81	13.4	"	9.70	1.30	14.68
B-471	"	N	"	"	"	"	"	"	"	-	84.1	1.032	5.51	2.95	2.45	27.55	4.7	.123	.0388	3.17	11.9	"	11.02	1.31	16.01
A-733	"	S	W	"	6000	"	"	"	"	"	89.5	.903	4.85	3.10	2.67	30.17	10.1	.146	.0461	3.16	16.2	"	9.70	1.57	14.95
B-473	"	N	"	"	"	"	"	"	"	"	85.4	1.036	5.53	2.95	2.71	30.62	6.0	.151	.0474	3.18	14.6	"	11.06	1.61	16.35

Sheet 2 Span 10

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L.L. Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec			
No.	Series			Class	Eng No.	H B at 1RPS.	Weight (Kips) Eng	Weight (Kips) Tender	No.	Kind	at Dist. "P"	Defl. (ins) "D"			R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)				D.L.	L.L.	Imp.	Total
A-732	1	S	W	H5L I	6000	2092	275.7	136.0	No	ne	87.0	.905	4.86	3.10	2.71	30.62	7.6	.151	.0474	3.18	16.7	3.68	9.72	1.62	15.02
B-472	"	N	"	"	"	"	"	"	"	"	84.0	1.036	5.53	2.95	2.75	31.07	4.6	.151	.0488	3.09	14.6	"	11.06	1.61	16.35
A-736	"	S	W	"	6000	"	"	"	"	-	84.9	.897	4.79	3.10	2.75	30.96	5.5	.175	.0488	3.60	19.5	"	9.58	1.87	15.13
B-476	"	N	"	"	"	"	"	"	"	"	84.4	1.037	5.53	2.95	2.76	31.06	5.0	.181	.0492	3.68	17.5	"	11.06	1.94	16.68
A-735	"	S	W	"	6000	"	"	"	"	"	86.5	.898	4.79	3.10	2.84	31.96	7.1	.171	.0521	3.28	19.0	"	9.58	1.82	15.08
B-475	"	N	"	"	"	"	"	"	"	"	84.0	1.034	5.52	2.95	2.88	32.42	4.6	.171	.0535	3.20	16.5	"	11.04	1.82	16.54
A-737	"	S	W	"	6000	"	"	"	"	"	88.2	.894	4.77	3.11	2.89	32.54	8.8	.169	.0539	3.14	18.9	"	9.54	1.80	15.02
B-477	"	N	"	"	"	"	"	"	"	"	84.9	1.039	5.54	2.94	2.85	32.07	5.5	.171	.0525	3.26	16.5	"	11.08	1.83	16.59
A-734	"	S	W	"	6000	"	"	"	"	"	88.3	.881	4.70	3.13	2.88	32.42	8.9	.171	.0535	3.20	19.3	"	9.40	1.81	14.89
B-474	"	N	"	"	"	"	"	"	"	"	84.3	1.039	5.54	2.94	2.92	32.86	4.9	.169	.0551	3.07	16.3	"	11.08	1.81	16.57
	Tests		A-	720-725- Aver. South Truss							89.8	.850	4.54	3.17			10.4					3.58	9.08		
			B-	460-465 " North Truss							89.9	1.001	5.35	2.99			10.5					"	10.70		
		Aver. Correcting for 95% Deflec. Factor										.910	4.86	3.10								3.58	9.72		
												.921	4.92	3.08								"	9.84		
	Tests		A-	727-737- Aver. South Truss							89.0	.893	4.78				9.6					3.58	9.56		
			B-	467-477 " North Truss							86.7	1.035	5.52	2.95			7.3					"	11.04		
		Aver. Correcting for 95% Deflec. Factor										.956	5.10	3.04								3.58	10.20		
												.952	5.08	3.04								"	10.16		
	NOTE:-	Engine took water after test A 725 and B-465. There was evidently some settlement under the bearings																							
			of the north truss and some binding in the expansion bearings of the south truss. With the assumed																						
			deflec. factor of 0.95, the deflections, E.U. Live Loads and L.L. Stresses in the south truss should be increased																						
			about 7% and those for the north truss decreased about 8%.																						
A-726	1	S	W	Gasoline	Motor	Train				P		.322	1.72			25.17		.003	0		1.0	3.68	3.42		
B-466	"	N	"	"	"	"				"		.392	9.09			25.17		.002	0		.5	"	4.18		

From Test B-746 we find an oscillation of .181 inch, at a speed of 2.76 r.p.s., and a dynamic magnifier of 3.68. The adjusted loaded frequency, n, is 3.04, and the damping factor, Δ, is found to be .229, giving a damping constant, p, of .0376. This is somewhat large for so shallow a span of this length, but a large portion of it probably represents friction damping.

The theoretical and actual values of the oscillations and dynamic magnifiers are shown in Fig. 47. There is an indication that spring damping was beginning to have its effect at a speed of 2.8 r.p.s. If such was the case, the spring friction was between 14 and 15 per cent. It seemed inadvisable at the time to run at any higher speed with this locomotive, as this class of engine had previously been limited to a speed of 5 m.p.h. The old formula would predict an impact of 60 per cent in this span, while the maximum measured impact was about 20 per cent, and considering its weight, the locomotive had quite a large hammer blow, 2090 lb. If a heavily loaded car had been used with this engine, the measured impact would have been still less.

SPAN NO. 11

A single track pin connected through truss, 122 ft., 3 in. long, and 27 ft., 3 in. deep, center to center of chords. See Fig. 48.

Like Span No. 10, this is an old bridge, designed for a light load, and was tested primarily for the purpose of determining its actual capacity. Otherwise it would not have been selected for testing as some of the eye-bars were quite slack, especially the center diagonals, and the expansion bearings were in poor condition.

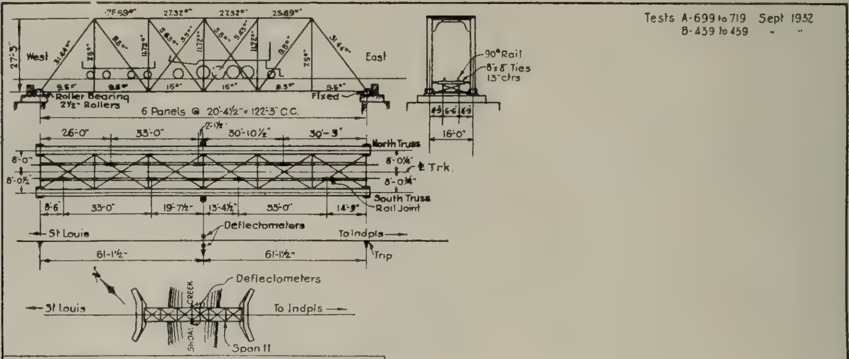
The same single locomotive, used in testing Span No. 10, was used on this bridge. The theoretical deflection under this loading is .841 inch, while the average measured deflection was .944 inch, giving a deflection factor of 1.122. Subsequently the loose eye-bars were tightened and while making the adjustment in tension, the deflection was again measured under a similar locomotive, and the deflection factor was found to be 1.106. The deflections were measured at the center, and it is quite likely that they were excessive on account of pin wear at that point. It will be noticed, in Table XXV, that from Tests A-701 to A-707, the south truss deflected more than the north. At this time the oscillations apparently became large enough to start movement in the north truss bearing, as from Test A-708 to A-716, the north truss had the greater deflection. At this time the south expansion bearings were probably forced into play, as from then on the south truss had the greater deflection. The mean of the deflections of the two trusses is quite constant, however, taking into account the consumption of coal and water during the test, the unequal distribution being due to end friction, which was only overcome when the oscillations became violent enough to unlock the rollers.

Using the deflection factor of 1.106, the dead load deflection is .2829 inch; the unloaded frequency is 6.51, and hammer blow deflection, D_h is .00621 inch.

Test B-457 has an oscillation of .198 inch at 2.88 r.p.s., and a dynamic magnifier of 3.82. The average loaded frequency, n, is 3.12, and we find the damping factor, Δ to be .235 and the damping constant, p, to be .0377.

From Test B-459, which has an oscillation of .159 inch at 2.81 r.p.s., we find that Δ is .250 and that p is .0399. The lower value, which will be used, is the same as that found in Span No. 10, and is undoubtedly somewhat high due to the condition of the expansion bearings.

The theoretical and measured oscillations and dynamic magnifiers are shown in Fig. 49. There was only one test in which the oscillation was greater than $\frac{0.15}{.1022N^3}$ which might lead us to believe that spring friction was not overcome and that the springs



DESIGN DATA

Date 1892 Spec. 1893
Material Soft Steel
Loading E-30 2 E.U.L.L. 4100
Flange Stress D.L. 3080
(Tens.N.Sec.) L.L. 8100
Imp. 810
Total 11990

Gross M.of I.at Center
Weight Steel per Ft. 1100
Weight Deck per Ft. 420
Total per Ft. 1520
Total for Span 186000

COMPUTED DEFLECTION
Theoretical 100% Factor

For 1000 Lbs.per Ft.Trk. .1685
For 1000 Lbs.at Center .00310
D.L. Deflection .2558
D.L. Frequency 7.86

COMPUTED FROM TESTS

Deflec.1000 Lbs.per Ft.Trk. .1861
Deflec.1000 Lbs.at Center .00343
Deflec.D.L. .2829
Frequency D.L. 6.51
$\frac{\text{Observed Defl.}}{\text{Computed Defl.}} = 1.106$

LOCOMOTIVES USED IN TESTS

Class of Engines	K3L									
Engines per class	1									
Tests per class	2									
Class of Engines	H5L (I)	H5T								
Engines per class	1	1								
Tests per class	38	2								

SPAN 11

Bridge 443 St Louis Div
Single Span, Single Track
122'-3" Thru Truss
Pin Connected

Fig. 48

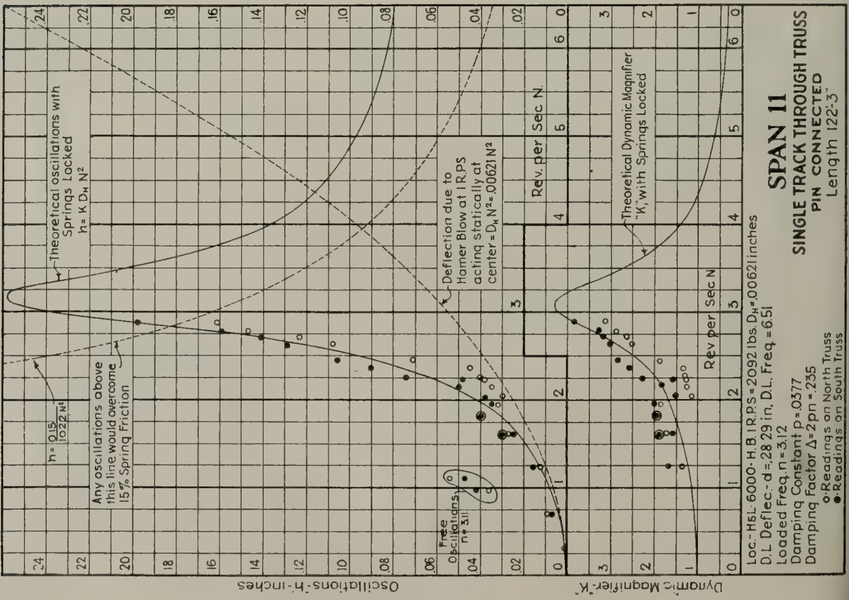


Fig. 49

TABLE XXV

122'-3" SINGLE TRACK PIN CONNECTED THROUGH TRUSS-DEPTH 27'-3'

Sheet 1 Span 11

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact γ%	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P	Defl (ins) 'D			R.P.S. 'N'	M.P.H	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-701	I	N	W	H5-L I	6000	2092	2757	1200	None		860	938	5.04	3.13	30	334	80	000	0005	–	0	3.08	1021		1329
B-441	"	S	"	"	"	"	"	"	"	"	889	.960	516	3.11	.30	334	109	.000	0005	–	0	"	10.45		1353
A-702	"	N	W	"	6000	"	"	"	"	"	87.8	924	496	315	.70	783	9.8	.009	.0030	3.00	1.0	"	1004	.10	13.22
B-442	"	S	"	"	"	"	"	"	"	"	86.8	.970	5.21	3.09	.70	7.86	88	.007	.0030	233	10	"	1055	08	1371
A-703	"	N	W	"	6000	"	"	"	"	"	86.5	934	5.02	314	.97	10.93	8.5	Free .036	.0058	621	39	"	10.17	.40	1365
B-443	"	S	"	"	"	"	"	"	"	"	87.2	960	516	311	.97	10.86	9.2	Free .042	0058	724	44	"	1045	.46	1399
A-704	"	N	W	"	6000	"	"	"	"	"	88.0	.929	499	3.15	1.10	12.38	10.0	Free .054	.0075	720	58	"	1010	.59	1377
B-444	"	S	"	"	"	"	"	"	"	"	877	.959	5.15	3.11	111	12.48	9.7	Free 047	.0076	6.19	49	"	1043	.51	14.02
A-706	"	N	W	"	6000	"	"	"	"	"	854	.924	4.96	3.15	124	13.96	7.4	013	0095	137	1.4	"	1004	.14	1326
B-446	"	S	"	"	"	"	"	"	"	"	87.7	958	515	3.11	124	13.98	9.7	.016	.0095	168	17	"	1043	.17	1368
A-707	"	N	W	"	6000	"	"	"	"	"	86.0	.937	5.03	3.14	159	1790	8.0	.030	.0157	1.90	3.2	"	10.19	.33	13.60
B-447	"	S	"	"	"	"	"	"	"	"	872	.950	5.10	3.12	160	17.93	9.2	.030	.0159	1.89	32	"	1033	.33	13.74
A-705	"	N	W	"	6000	"	"	"	"	"	87.1	.929	4.99	3.15	161	18.08	9.1	.027	0161	168	2.9	"	10.10	.29	13.47
B-445	"	S	"	"	"	"	"	"	"	"	865	.966	5.19	3.10	162	18.18	8.5	.025	0162	154	26	"	10.51	.27	1396
A-708	"	N	W	"	6000	"	"	"	"	"	852	.953	5.12	3.12	1.82	2046	7.2	.040	.0205	1.95	42	"	1037	.43	13.88
B-448	"	S	"	"	"	"	"	"	"	"	876	.927	4.98	3.15	182	2046	9.6	.040	.0205	1.95	43	"	1008	.43	1359
A-709	"	N	W	"	6000	"	"	"	"	"	86.7	.955	5.13	3.11	195	21.88	8.7	.032	.0236	1.35	3.4	"	10.39	35	13.82
B-449	"	S	"	"	"	"	"	"	"	"	88.8	.936	5.03	3.14	1.94	2179	10.8	.035	0233	1.50	3.7	"	10.19	.38	13.65
A-710	"	N	W	"	6000	"	"	"	"	"	87.1	.943	5.07	3.13	204	2291	9.1	030	.0258	116	3.2	"	10.27	.33	1368
B-450	"	S	"	"	"	"	"	"	"	"	87.6	.936	5.03	3.14	2.02	22.73	9.6	.038	.0253	150	41	"	10.19	.42	1369
A-713	"	N	W	"	6000	"	"	"	"	"	85.8	.940	5.05	3.13	214	24.18	7.8	.035	.0274	127	37	"	10.23	38	13.69
B-453	"	S	"	"	"	"	"	"	"	"	844	.925	4.97	3.15	2.14	2418	6.4	.050	.0274	186	54	"	10.06	.54	13.68
A-711	"	N	W	"	6000	"	"	"	"	"	85.3	.941	5.06	3.13	2.20	2486	7.3	.038	.0300	1.27	4.0	"	10.25	.41	13.74
B-451	"	S	"	"	"	"	"	"	"	"	83.7	.940	5.05	3.13	2.24	25.31	5.7	.048	.0311	154	5.1	"	10.23	.52	13.83

Sheet 2 Span 11

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact γ%	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P	Defl (ins) D			R.P.S. 'N'	M.P.H.	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
A 712	I	N	W	H5L I	6000	2092	2757	1200	None		859	942	506	313	223	2520	79	040	.0308	129	43	308	1025	44	1377
B-452	"	S	"	"	"	"	"	"	"	"	841	.930	500	315	226	2554	61	074	0317	233	80	"	1013	.81	1408
A-714	"	N	W	"	6000	"	"	"	"	"	86.0	943	507	313	236	2653	80	045	0345	1.31	48	"	1027	.49	1384
B-454	"	S	"	"	"	"	"	"	"	"	855	937	503	314	236	2653	75	.090	0345	262	96	"	1019	98	1425
A-715	"	N	W	"	6000	"	"	"	"	"	839	947	509	312	246	2766	59	.071	0375	189	7.5	"	1031	.77	1416
B-455	"	S	"	"	"	"	"	"	"	"	839	938	504	313	243	2737	59	.106	0366	289	113	"	10.21	115	1444
A-716	"	N	W	"	6000	"	"	"	"	"	874	.934	502	314	2.63	2948	94	108	.0429	251	116	"	1017	118	1443
B-456	"	S	"	"	"	"	"	"	"	"	840	954	513	311	263	2960	6.0	.129	0429	301	135	"	1039	141	1488
A-718	"	N	W	"	600	"	"	"	"	"	846	934	502	314	275	3090	6.6	.123	0468	263	132		1017	134	1459
B 458	"	S	"	"	"	"	"	"	"	"	833	946	508	312	268	3016	53	141	.0445	317	149	"	1029	153	1490
A-719	"	N	W	"	600	"	"	"	"	"	834	937	503	314	277	3130	54	.137	0475	289	146	"	1019	149	1476
B-459	"	S	"	"	"	"	"	"	"	"	829	938	504	313	2.81	3175	49	.159	.0490	325	170		1021	173	1502
A-717	"	N	W	"	600	"	"	"	"	"	85.0	.932	501	314	288	3254	7.0	.161	.0514	313	173	"	1015	175	1498
B-457	"	S	"	"	"	"	"	"		"	827	.953	512	312	289	3265	47	198	0518	382	208	"	1037	216	1561
			Average North Truss				2757	1200			859	.943	507	313			79					3.08	1027		
				" South Truss			"	"			858	.946	508	3.12			78					"	1029		
A 700	I	N	W	H5T	6087	2092	2855		–	F	8/5	955	513	311	183	2068	95	020	0208	98	21	308	1039	.22	1369
B-440	"	S	"	"	"	"	"		"	"	850	998	536	306	185	2090	70	035	021	118	35	"	1085	38	1431
A-699	I	N	W	K3L	6473	1605	2740		3	P	909	941	5.06	313	233	3285	113	059	0271	218	63	308	1025	64	1397
B-439	"	S	"	"	"	"	"		"	"	900	.941	506	3.13	235	3313	104	049	0276	179	52	"	1025	53	1386

remained locked, although on Span No. 10 there was evidence that the spring friction of this same locomotive was not more than 15 per cent of the sprung weight. This one oscillation of .198 inch was measured in the south truss, while for the same run the oscillation in the north truss was only .161 inch. The average of .180 would just about fall on the 15 per cent friction line (see Fig. 49), so that with higher speeds, if they could have been attained, it is quite possible that spring damping would be apparent, as was the case in Span No. 10.

SPAN NO. 12

A single track pin connected through truss having five panels 110 ft. long, 25 ft. deep, center to center of chords. The span is supported on timber piers. See Fig. 50.

This was one of the light bridges which under the old impact formula would be limited to light power, and was investigated for this reason, rather than as an ideal span for impact tests. The fact that it contained an odd number of panels and that it was carried on timber introduced several complications.

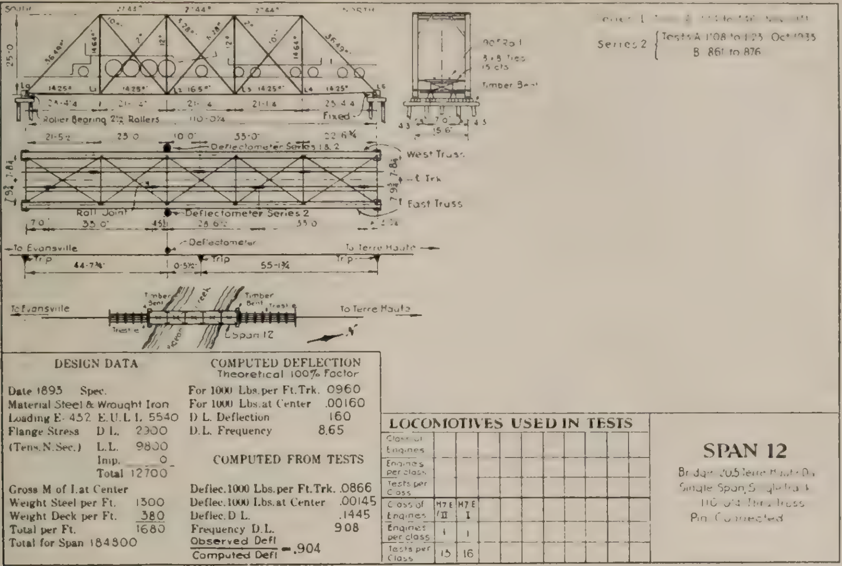
Two series of tests were run. The first was with an H7-E, Type II locomotive and two loaded cars, one deflectometer, located at panel point 2 on the west truss was used. By means of a level the deflections at each panel point on both trusses and the settlement of the bents under each bearing were measured while the train was standing on the bridge. A second series was run later, using an H7-E, Type I locomotive with two loaded cars. These engines are alike as to hammer blow, but vary slightly as to weight; there was also some difference in tender and car loading between the two tests. In this series a deflectometer was used on both trusses, located at panel point 2.

After making correction for pier settlement, the average deflection of the west truss, series 1, was .604 inch, and for series 2, the average deflection for the west truss was .620 inch, and for the east truss .615 inch. From the calculated theoretical deflection, a deflection factor of .904 was obtained. This seems a little high, as there was no apparent pin play, and the eye-bars were in good adjustment. Owing to compression under the bearings, it is difficult to obtain an accurate value for this factor, but from strain gage reading, taken during the first series of tests, it is evident that the floor system was taking an unusually small proportion of the bottom chord stress, which would account for this rather high factor. Assuming that it is about right, the dead load deflection should be .1445 inch and the hammer-blow deflection, D_h, .00375 inch for the west truss, and .00372 inch for the east truss.

The usual method of calculating the natural frequency cannot be used in this case, as the movement at the bearings affects the inertia of the vibrating span. From the second set of tests, it is apparent that each truss has a different frequency, that for the west being about 3.55, and for east 3.40. Using these values, we find that the damping constant, p, is .033.

In Fig. 51 are shown the theoretical and measured values of the dynamic magnifiers and oscillations. It is interesting to note the difference in the behavior of these two locomotives, which are supposedly alike. In the first series of tests, Engine No. 6170 was used, and after a speed of 3 r.p.s. was passed, the oscillations became smaller, and we can only ascribe this to locomotive spring damping, the spring friction being about 10 per cent. In the second series, the oscillations from Engine 6151 increased in magnitude until the synchronous speed was reached, after which they became smaller, as they should, when the locomotive springs remain inactive.

While in many, if not most, instances such damping does take place, resulting in small oscillations and impacts at the lower or first synchronous speed, it is evident that it is not safe to assume that such damping will always be present, in fixing an impact allowance.



Series 2 Tests A 1108 to 1125 Oct 1935
B 861 to 876

DESIGN DATA

Date 1893 Spec.
Material Steel & Wrought Iron
Loading E-45½ E.U.L.L. 5540
Flange Stress (Tens.N.Sec.) D.L. 2900
L.L. 9800
Imp. 0
Total 12700
Gross M of I at Center
Weight Steel per Ft. 1300
Weight Deck per Ft. 380
Total per Ft. 1680
Total for Span 184800

COMPUTED DEFLECTION
Theoretical 100% Factor

For 1000 Lbs. per Ft. Trk. .0960
For 1000 Lbs. at Center .00160
D.L. Deflection .160
D.L. Frequency 8.65

COMPUTED FROM TESTS

Deflec. 1000 Lbs. per Ft. Trk. .0866
Deflec. 1000 Lbs. at Center .00145
Deflec. D.L. .1445
Frequency D.L. 9.08

$\dfrac{\text{Observed Defl}}{\text{Computed Defl}} = .904$

LOCOMOTIVES USED IN TESTS

Class of Engines										
Engines per class										
Tests per Class										
Class of Engines	H7E / II	H7E I								
Engines per class	1	1								
Tests per Class	15	16								

SPAN 12

Bridge 20.5 Terre Haute Di.
Single Span, Single Track
110'0¾ Thru Truss
Pin Connected

Fig. 50

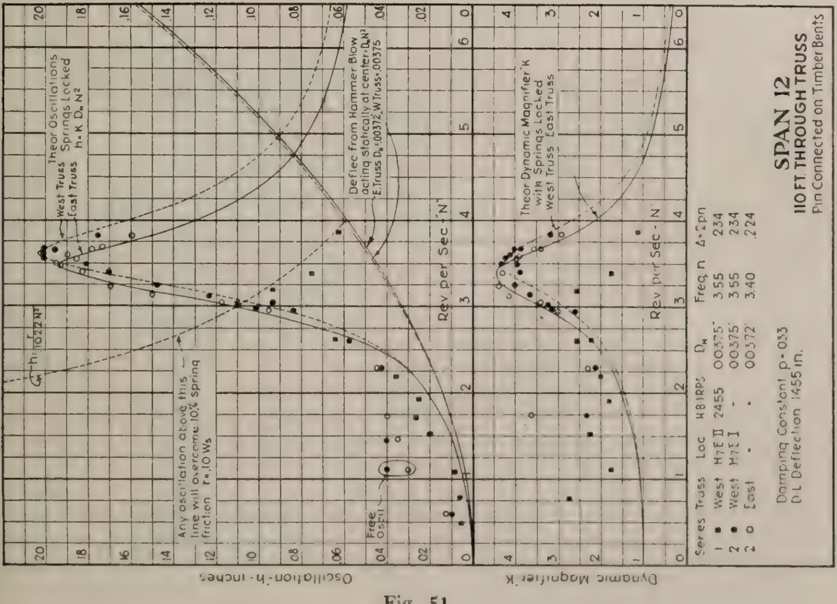


Fig. 51

TABLE XXVI

SINGLE TRACK- PIN CONNECTED THROUGH TRUSS-110 FT. Lg. ON TIMBER BENTS.

Sheet 1 Span 12

Test No.	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1RPS	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist "P"	Stat L L Defl Defl (ins) D	E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed R.P.S. "N"	Speed M.P.H.	Hammer Blow Dist "H" (Ft.)	Hammer Blow Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec DL	LL	Imp.	Total
A-334	1	W	S	H7E-II	6170	2455	334.9	160.0	2	F	94.8	.618	7.14		0.49	5.48	11.7	.005	.0009	5.55	0.8	2.90	12.35	.10	15.35
A-335	"	"	"	"	"	"	"	"	"	"	97.0	.613	7.08		0.77	8.66	13.9	.006	.0022	2.73	0.9	"	12.25	.11	15.26
A-336	"	"	"	"	"	"	"	"	"	"	94.7	.605	6.99	Average from Tests-3.55	1.09	12.21	11.6	.008	.0045	1.77	1.3	"	12.09	.16	15.15
A-337	"	"	"	"	"	"	"	"	"	"	95.7	.605	6.99		1.52	17.11	12.6	.020	.0088	2.27	3.3	"	12.09	.40	15.39
A-338	"	"	"	"	"	"	"	"	"	"	92.2	.595	6.87		1.92	21.56	9.1	.025	.0138	1.81	4.2	"	11.89	.50	15.29
A-339	"	"	"	"	"	"	"	"	"	"	95.1	.597	6.89		2.19	24.66	12.0	.036	.0180	2.00	6.0	"	11.92	.72	15.54
A-341	"	"	"	"	"	"	"	"	"	"	99.0				2.60	29.38	15.9	.064	.0254	2.52		"			
A-346	"	"	"	"	"	"	"	"	"	"	92.5	.595	6.87		2.61	29.49	9.4	.057	.0255	2.24	9.6	"	11.89	1.14	15.93
A-342	"	"	"	"	"	"	"	"	"	"	95.3	.597	6.89		2.97	33.29	12.2	.101	.0321	3.14	16.8	"	11.92	2.00	16.82
A-340	"	"	"	"	"	"	"	"	"	"	96.4	.621	7.17		3.02	33.93	13.3	.110	.0342	3.22	17.7	"	12.41	2.20	17.51
A-343	"	"	"	"	"	"	"	"	"	"	97.5	.598	6.90		3.18	35.76	14.4	.094	.0379	2.53	15.7	"	11.94	1.87	16.71
A-345	"	"	"	"	"	"	"	"	"	"	97.4				3.36	37.76	14.3	.075	.0424	1.77		"			
A-344	"	"	"	"	"	"	"	"	"	"	92.3	.598	6.90		3.86	43.40	9.2	.063	.0559	1.13	10.5	"	11.94	1.25	15.09
			Average-West Truss				334.9	160.0			95.4	.604	6.98				12.3					2.90	12.07		
A-1110	2	W	S	H7E-I	6151	2455	328.0	176.0	2	F	94.5	.629	7.26		0.64	7.23	11.4	.010	.0015	6.67	1.6	2.90	12.56	.20	15.66
B-863	"	E	"	"	"	"	"	"	"	"	95.0	.623	7.20		0.66	7.46	11.9	.012	.0016	7.50	1.9	"	12.46	.24	15.60
A-1109	"	W	S	"	6151	"	"	"	"	"	96.0	.615	7.10		1.12	12.66	12.9	Free .040	.0047	8.50	6.5	"	12.28	.80	15.98
B-862	"	E	"	"	"	"	"	"	"	"	94.5	.634	7.32		1.11	12.54	11.4	Free .030	.0046	6.52	4.7	"	12.67	.59	16.16
A-1111	"	W	S	"	6151	"	"	"	"	"	93.5	.607	7.01		1.46	16.50	10.4	.040	.0080	5.0	6.6	"	12.11	.80	15.81
B-864	"	E	"	"	"	"	"	"	"	"	94.0	.628	7.25		1.45	16.39	10.9	.035	.0078	4.48	5.6	"	12.54	.70	16.14
A-1112	"	W	S	"	6151	"	"	"	"	"	90.8	.619	7.15		1.75	19.78	7.7	.027	.0015	2.35	4.4	"	12.37	.54	16.81
B-865	"	E	"	"	"	"	"	"	"	"	90.5	.617	7.12		1.72	19.44	7.4	.040	.0110	3.63	6.5	"	12.32	.80	16.02
A-1113	"	W	S	"	6151	"	"	"	"	"	90.8	.618	7.13		2.29	25.88	7.7	.043	.0197	2.18	7.0	"	12.34	.86	16.11
B-866	"	E	"	"	"	"	"	"	"	"	94.2	.611	7.06		2.29	25.88	11.1	.045	.0195	2.31	7.3	"	12.21	.89	16.00

Sheet 2 Span 12

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No	Locomotive H B at 1RPS	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist "P"	Stat L L Defl Defl (ins) D	E U L L (Kips)	Loaded Frequency n	Speed R P S "N"	Speed M P H	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact %	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A-1114	2	W	S	H7E-I	6151	2455	328.0	176.0	2	F	87.5	.629	7.26		2.95	33.34	4.4	.084	.0326	2.58	13.3	2.90	12.56	1.67	17.13
A-867	"	E	"	"	"	"	"	"	"	"	95.4	.619	7.15		2.95	33.34	12.3	.096	.0323	2.97	15.5	"	12.37	1.92	17.19
A-1115	"	W	S	"	"	"	"	"	"	"	92.7	.633	7.31		3.05	34.47	9.6	.094	.0349	2.70	14.9	2.90	12.65	1.88	17.43
B-868	"	E	"	"	"	"	"	"	"	"	91.0	.606	7.00		3.05	34.47	7.9	.118	.0346	3.41	19.4	"	12.08	2.34	17.32
A-1116	"	W	S	"	"		"	"	"	"	91.0	.625	7.22		3.12	35.26	7.9	.134	.0365	3.67	21.4	"	12.49	2.67	18.06
B-869	"	E	"	"	"	"	"	"	"	"	89.0	.610	7.05		3.12	35.26	5.9	.150	.0362	4.14	24.6	"	12.19	3.00	18.09
A-1123		W	S	"	"	"	"	"	"	"	92.0	.619	7.16		3.22	36.39	8.9	.158	.0389	4.07	25.5	"	12.37	3.15	18.42
B-876	"	E	"	"	"	"	"	"	"	"	87.2	.598	6.90	Average from Tests– East Truss - 3.40 West Truss - 3.55	3.22	36.39	4.1	.170	.0386	4.40	28.4	"	11.94	3.39	18.23
A-1108	"	W	S	"	"	"	"	"	"	"	92.0	.633	7.31		3.43	38.76	8.9	.171	.0441	3.88	27.0	"	12.65	3.41	18.96
B-861	"	E		"	"	"	"	"	"	"	92.2	.618	7.14		3.39	38.31	9.1	.183	.0427	4.29	29.6	"	12.35	3.66	18.91
A-1117	"	W	S		"	"	"	"	"	"	92.5	.617	7.12		3.50	39.55	9.4	.181	.0459	3.94	29.3	"	12.32	3.61	18.83
B-870	"	E	"	"	"	"	"	"	"	"	89.5	.610	7.05		3.49	39.44	6.4	.196	.0453	4.33	32.1	"	12.19	3.91	18.99
A-1118	"	W	S	"	"	"	"	"	"	"	92.3	.625	7.22		3.54	39.99	9.2	.201	.0470	4.28	32.2	"	12.49	4.02	19.41
B-871	"	E	"	"	"	"	"	"	"	"	89.7	.620	7.16		3.56	40.16	6.6	.186	.0471	3.95	30.0	"	12.39	3.72	19.01
A-1119	"	W	S	"	"	"	"	"	"	"	92.8	.627	7.25		3.59	40.57	9.7	.201	.0483	4.12	32.1	"	12.54	4.01	19.45
B-872	"	E	"	"	"	"	"	"		"	89.5	.614	7.09		3.59	40.57	6.4	.191	.0490	3.90	31.1	"	12.27	3.82	18.99
A-1120	"	W	S	"	"		"	"	"	"	94.5	.617	7.12		3.66	41.36	11.4	.195	.0503	3.87	31.6	"	12.32	3.89	19.09
B-873	"	E		"	"	"	"	"	"	"	87.5	.609	7.04		3.67	41.37	4.4	.178	.0498	3.58	29.2	"	12.17	3.55	18.62
A-1122		W	S	"	"		"	"	"	"	91.8	.615	7.10		3.67	41.37	8.7	.203	.0506	4.01	33.0	"	12.28	4.05	19.23
B-875	"	E	"	"	"	"	"	"	"		88.0	.618	7.14		3.67	41.37	4.9	.174	.0502	3.47	28.1	"	12.35	3.47	18.72
A-1121		W	S	"	"	"	"	"	"	"	92.0	.607	7.02		3.82	43.16	8.9	.176	.0550	3.20	29.0	"	12.14	3.52	18.56
B-874		E	"	"	"		"	"	"		87.1	.610	7.05		3.84	43.39	4.0	.161	.0546	2.95	26.4	"	12.19	3.22	18.31
	Average-			West Truss			328.0	176.0			92.3	.620	7.16				9.2					2.90	12.39		
		"		East Truss							90.4	.615	7.10				7.3					"	12.28		

SPANS 13 and 14

Deck girder spans, 103 ft. 8 in. long over all, 100 ft. 8 in. center to center of bearings. These spans are alike in all respects. See Fig. 52.

Owing to the location of this bridge it was impossible to obtain runs at high speed, but from one or two tests it was possible to obtain the damping constant, which was found to be .026. The deflection factor for both spans was found to be 1.105.

The theoretical and measured oscillations and dynamic magnifiers have been plotted, and are shown in Fig. 53.

SPANS 15 and 16

Deck girder spans with skew ends, 100 ft. over all and 98 ft. center to center of bearings. The spans are alike except as to the deck. See Fig. 54.

Tests were made on these spans, at three different times. The oscillations at the higher speeds seem to be damped by spring action. The theoretical oscillations, for Case II, have been computed for the J1-D locomotive, using a spring friction equal to 11.5 per cent of the sprung weight. The agreement between the theoretical and actual oscillations is fair only, but it should be remembered that ten different locomotives of this class are represented in the tests. See Fig. 55.

From the tests, which apparently were unaffected by spring action, the damping constant was found to be .0282. The deflection factor is 1.134.

SPANS 17 and 18

Deck girder spans 96 ft. 6 in. long over all, and 94 ft. 2 in. center to center of bearings. These spans are alike and are shown in Fig. 56.

Span No. 17 was tested with an H10-A—Type II locomotive, this being a heavy engine with a small hammer blow. An H6-A locomotive, which is comparatively light but has a large amount of overbalance, was used on span 18.

For span 17, Δ was found to be .1798, and for span No. 18, it was .1910, giving a value of .0281, for the damping constant, on both spans. The measured and theoretical oscillations are shown in Fig. 57. The runs were scarcely fast enough to produce vibrations which would overcome spring friction.

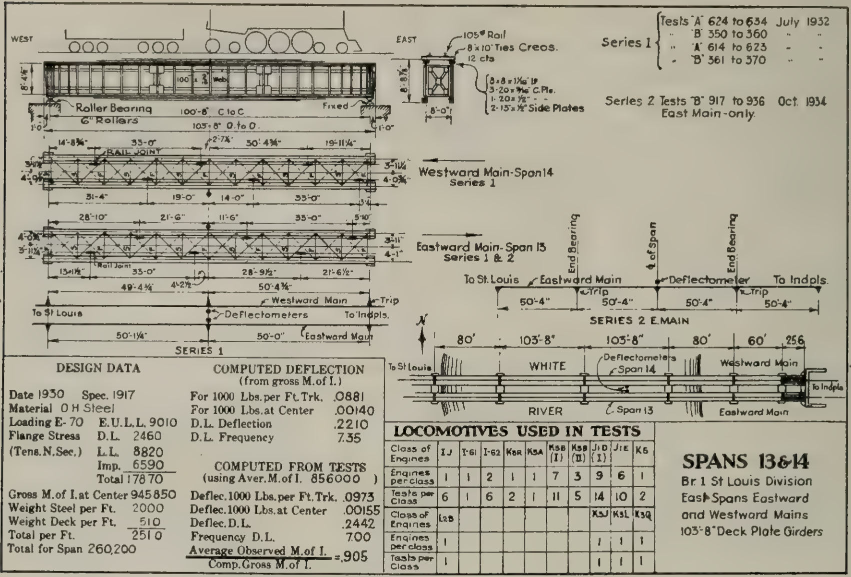
The deflection factor was found to be 1.120.

SPAN NO. 19

A deck girder span, 91 ft. 2 in. long over all, and 88 ft. 11 in. center to center of bearings. See Fig. 58.

At speeds greater than 4 r.p.s., most of the oscillations seem to be damped, probably as a result of spring action. The damping constant was found to be .0298, and the deflection factor is 1.100. A comparison between the theoretical and measured oscillations is shown in Fig. 59.

This span is in the same bridge as span No. 29, both girders being tested at the same time.



Series 1
Tests "A" 624 to 634 July 1932
" "B" 350 to 360 " "
" "A" 614 to 623 - -
" "B" 361 to 370 " "

Series 2 Tests "B" 917 to 936 Oct. 1934
East Main-only

DESIGN DATA

Date 1930	Spec. 1917	
Material	O H Steel	
Loading E-70	E.U.L.L.	9010
Flange Stress	D.L.	2460
(Tens. N. Sec.)	L.L.	8820
	Imp.	6590
	Total	17870
Gross M. of I. at Center		945850
Weight Steel per Ft.		2000
Weight Deck per Ft.		510
Total per Ft.		2510
Total for Span		260,200

COMPUTED DEFLECTION
(from gross M. of I.)

For 1000 Lbs. per Ft. Trk.	.0881
For 1000 Lbs. at Center	.00140
D.L. Deflection	.2210
D.L. Frequency	7.35

COMPUTED FROM TESTS
(using Aver. M. of I. 856000)

Deflec. 1000 Lbs. per Ft. Trk.	.0973
Deflec. 1000 Lbs. at Center	.00155
Deflec. D.L.	.2442
Frequency D.L.	7.00

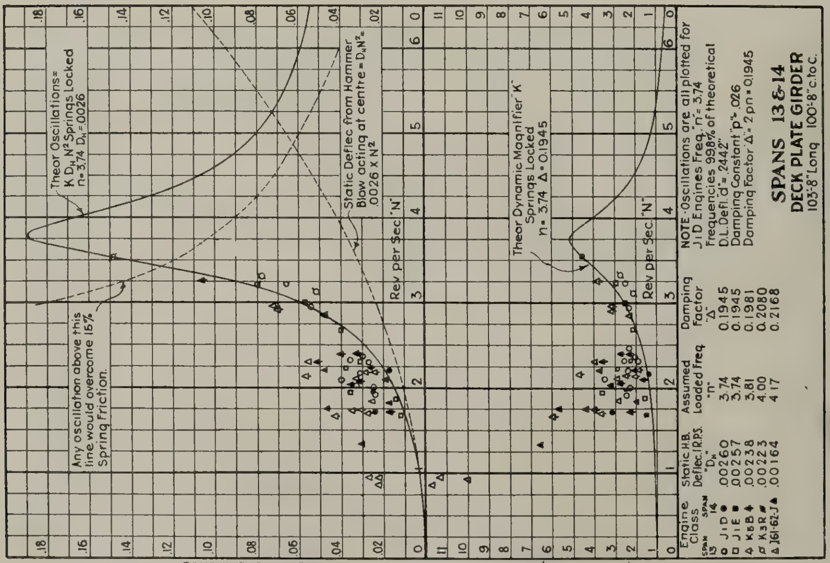
$$\frac{\text{Average Observed M. of I.}}{\text{Comp. Gross M. of I.}} = .905$$

LOCOMOTIVES USED IN TESTS

Class of Engines	I J	I-61	I-62	K5R	K5A	K5B (I)	K5B (II)	J1D (I)	J1E	K6
Engines per class	1	1	2	1	1	7	3	9	6	1
Tests per Class	6	1	6	2	1	11	5	14	10	2
Class of Engines	L2B							K5J	K5L	K3Q
Engines per class	1							1	1	1
Tests per Class	1							1	1	1

SPANS 13&14
Br. 1 St Louis Division
East Spans Eastward
and Westward Mains
103'-8" Deck Plate Girders

Fig. 52



Engine Class Span 13	Engine Class Span 14	Static H.B. Deflec. 1 R.P.S. "D_H"	Assumed Loaded Freq "n"	Damping Factor "Δ"
○ J1D	●	.00260	3.74	0.1945
□ J1E	■	.00257	3.74	0.1945
△ K5B	◆	.00238	3.81	0.1981
ø K3R	■	.00223	4.00	0.2080
△ I61-62-J	▲	.00164	4.17	0.2168

NOTE-Oscillations are all plotted for J1D Engines Freq. "n" = 3.74
Frequencies 99.8% of theoretical
D.L. Defl. "d" = .2442"
Damping Constant "p" = .026
Damping Factor "Δ" = 2pn = 0.1945

SPANS 13 & 14
DECK PLATE GIRDER
103'-8" Long 100'-8" c. to c.

Fig. 53

TABLE XXVII

BR Nº1 ST LOUIS DIV 103'-8" DP GIRDER EASTWARD MAIN

Sheet 1 Span 13

Test		Girder	Direc of Movement	Locomotive					Cars		Stat LL Defl		EULL (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow D, N² at Center	Dynamic Magnifier K	Impact γ%	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D			RPS N	MPH	Dist H (Ft)	Osc (ins)				DL	LL	Imp	Total
B 926	2	N	E	J1E	6621	1671	3515	2485	10	P	905	614	631	380	196	2756	210	056	0093	364	58	246	618	36	900
A 620	1	N		-	6621	-	-	2165	2		895	623	640	378	224	3157	200	038	0129	294	61	-	627	38	911
B 932	2	N		-	6629	-		2485	10		905	635	653	375	231	3255	210	031	0138	225	49	-	640	31	917
B 369	1	N	-	-	6622	-		2170	12		895	625	642	379	268	3784	200	040	0184	217	64	-	629	40	9 5
B-363	1	N	-	-	6627	-		2140	11		895	636	654	375	300	4240	200	056	0231	242	88	-	641	56	943
B 922	2	N	-	-	6628			2485	10	-	905	619	637	379	321	4530	210	079	0265	298	128		[illegible]	80	950
A 616	1	N	-		6628			2095	12		895	637	655	374	353	4971	200	147	032	460	230	-	642	148	1036
				Average							900	627	645	377			204					246	632		
B-920	2	N	E	J1D	6608	1690	3530	2470	-	P	915	631	648	375	194	2727	220	024	0098	245	38	246	635	24	905
B 366	1	N			6610			2070	3	-	893	618	635	378	200	2824	198	025	0104	240	390	-	622	24	892
B 919	2	N	-	-	6613			2485	10	-	915	640	657	374	202	2852	220	034	0106	320	53	-	644	.34	924
B 927	2	N	-	-	6608			2330	-	-	907	626	643	377	210	2935	212	040	0115	348	64	-	630	40	916
A-618	1	N	-	-	6610			2085	12	-	893	625	642	377	219	3081	198	030	0125	240	48		629	30	905
B 924	2	N	-		6606	-		2330	11	-	907	618	635	379	231	3261	212	027	0139	194	44	-	622	27	895
B-935	2	N	-		6611		-	2330	14		907	632	649	375	232	3275	212	036	0140	257	57	-	636	36	918
B-929	2	N			6619			1900	12		893	.624	641	377	237	3346	198	030	0146	206	48	-	628	.30	9.04
A 623	1	N	-	-	6600		-	2085	12		893	641	659	373	246	3384	198	037	0158	234	58	-	646	37	929
B 934	2	N			6612	-		2450	13		915	628	645	376	296	4178	220	054	0228	237	86		632	54	932
B-917	2	N			6611			2510	13		915	625	642	377	323	4548	220	066	0262	252	105	-	629	66	941
				Average							905	628	645	376			210					246	632		

Sheet 2 Span 13

Test		Girder	Direc of Movement	Locomotive					Cars		Stat LL Defl		EULL (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow D, N² at Center	Dynamic Magnifier K	Impact γ%	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D			RPS N	MPH	Dist H (Ft)	Oscil (ins)				DL	LL	Imp	Total
B-925	2	N	E	K5BII	6519	1560	3020	1690	3	P	877	581	598	386	170	2398	182	026	0069	377	45	246	586	.26	858
A-622	1	N	-	K5BI	6505	-	2975	2270	6	-	890	.591	608	383	173	2443	195	.028	.0071	394	47	-	596	28	870
B-918	2	N	-	K5BII	6517	-	3020	1930	3		877	.576	592	387	174	2459	18.2	.031	.0072	430	54	-	580	31	857
B-928	2	N	-	K5BI	6510	-	297.5	2150	4	-	877	555	571	392	214	3010	182	051	.0109	468	92	-	560	52	858
B-370	1	N	-	-	6506	-	-	1805	6	-	86.5	591	608	390	216	3039	170	027	0111	243	46	-	596	27	869
A-615	1	N	-	-	6509	-	-	2235	6	-	890	.603	620	380	219	3084	195	022	0114	193	37	-	608	22	876
B-364	1	N	-	K5BI	6514	-	2975	2300	8	-	890	593	610	383	291	4115	19.5	064	.0202	316	108	-	598	65	909
B 933	2	N	-	-	6514	-	-	2070	4		877	573	589	388	325	4586	182	097	0252	385	169	-	577	98	921
				Average							880	.583	600	385								246	588		
B 936	2	N	E	K5	6525	1671	3030	2140	8	P	884	594	612	381	164	2305	190	041	0069	594	69	246	600	.41	887
B-930	2	N	-	-	6525	-	-	2320	8	-	884	605	623	379	295	4159	190	.071	.0223	318	11.7	-	611	71	928
				Average							884	.600	618	380			190					246	606		
B-365	1	N	E	K3R	6500	1460	2780	1365	3	P	889	491	505	402	311	4378	194	045	0215	209	92	246	495	.46	787
A-617	1	N		-		-			-		889	503	518	399	333	4697	194	067	0247	271	133		508	68	822
				Average							889	497	511	400			194					246	501		
B-921	2	N	E	K3Q	6487	1650	2955	1460	4	P	860	540	556	392	211	2971	171	032	0114	280	59	246	545	32	823
B-931	2	N	E	K3J	6455	1603	2740	1425	8	P	860	511	526	405	183	2579	171	036	0081	445	71	246	515	37	798
B 923	2	N		K3L	6474	-	-	1120	4	-	86.0	476	490	416	306	4316	171	050	0226	221	105		480	50	776
				Average							860	494	508	410			171					246	498		

Sheet 3 Span 13

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L.L. Defl.		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist. "P"	Defl. (ins) "D"			R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)				D.L	L L	Imp.	Total
B-367	1	N	E	I 62	6916	1070	202.8	144.0	0	-	80.7	.451	4.63	4.12	0.86	12.08	-14.5	.014	.0012	11.7	3.1	2.46	4.54	0.14	7.14
B-361	"	"	"	I J	6954	"	200.0	144.0	0	-	80.0	.465	4.78	4.08	0.93	13.07	-14.2	.014	.0014	10.0	3.0	"	4.68	0.14	7.28
A-619	"	"	"	I 62	6915	"	202.8	144.0	0	-	80.7	.465	4.78	4.08	0.95	13.33	-14.5	.017	.0015	11.3	3.7	"	4.68	0.17	7.31
B-368	"	"	"	IJ	6954	"	200.0	103.5	3	P	85.6	.427	4.39	4.29	1.85	26.01	20.6	.016	.0056	2.86	3.7	"	4.30	0.16	6.92
A-614	"	"	"	I61	6912	"	200.9	103.5	3	P	85.7	.425	4.37	4.23	2.08	29.38	20.7	.020	.0071	2.82	4.7	"	4.28	0.20	6.94
B-362	"	"	"	I 62	6915	"	202.8	103.5	3	P	77.2	.437	4.49	4.23	2.31	32.55	12.2	.035	.0088	3.98	8.0	"	4.40	0.35	7.21
A-621	"	"	"	IJ	6954	"	200.0	103.5	3	P	85.6	.435	4.47	4.27	2.84	40.08	20.6	.030	.0132	2.27	6.9	"	4.38	0.30	7.14
					Average						82.2	.444	4.56	4.19			±16.8					2.46	4.46		

NOTE:- Frequencies shown are theoretical frequencies without damping;
actual frequencies are about 99.8% of above
D.L. Deflection = .2442"
Deflection per 1000# per ft. = .0973"
Stress per 1000# per ft. = 930#

TABLE XXVIII

BR. Nº1 ST. LOUIS DIV. 103'-8" D.P GIRDER WESTWARD MAIN

Sheet 1 Span 14

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency "c"	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng. No.	H. B at 1 RPS.	Weight (Kips) Eng	Weight (Kips) Tender	No.	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H.	Dist "H" (Ft.)	Oscil (ins)				D.L	L L	Imp.	Total
A-625	1	S	W	J1E	6626	1670	351.5	236.0	11	P	90.8	.642	6.59	3.70	1.67	23.58	20.3	.011	.0072	1.53	1.7	2.46	6.46	.11	9.03
B-360	"	"	"	"	6628	"	"	240.0	10	"	90.8	.623	6.40	3.74	1.87	26.40	20.3	.014	.0090	1.56	2.2	"	6.27	.14	8.87
A-631	"	"	"	"	6621	"	"	245.0	12	"	90.8	.635	6.52	3.71	1.98	28.04	20.3	.025	.0101	2.48	3.9	"	6.38	.26	9.09
					Average						90.8	.633	6.50	3.72			20.3					2.46	6.37		
B-351	1	S	W	J1D	6613	1690	353.6	237.0	12	P	90.7	.641	6.59	3.72	1.72	24.27	21.2	.024	.0077	3.12	3.7	2.46	6.46	.24	9.16
B-350	"	"	"	"	6605	"	"	254.5	7	"	91.5	.657	6.75	3.69	2.14	30.12	22.0	.030	.0119	2.52	4.6	"	6.62	.30	9.38
B-357	"	"	"	"	6610	"	"	237.0	11	"	90.7	.641	6.59	3.72	2.16	30.42	21.2	.017	.0122	1.40	2.7	"	6.46	.17	9.09
					Average						90.9	.646	6.64	3.71			21.4					2.46	6.51		
A-634	1	S	W	K-5A	6529	1560	301.0	268.0	7	P	91.1	.635	6.54	3.74	0.95	13.43	21.6	.013	.0021	6.20	2.0	2.46	6.41	.13	9.00
B-359	"	"	"	K-5B I	6507	"	297.5	"	7	"	90.8	.615	6.33	3.73	1.72	24.22	21.3	.016	.0070	2.28	2.6	"	6.20	.16	8.82
A-624	"	"	"	" "	6506	"	"	223.0	7	"	88.8	.595	6.13	3.82	2.06	29.04	19.3	.028	.0101	2.77	4.7	"	6.01	.28	8.75
B-354	"	"	"	" II	6524	"	302.5	268.0	8	"	91.1	.631	6.50	3.74	2.09	29.52	21.6	.017	.0104	1.63	2.7	"	6.37	.17	9.00
A-628	"	"	"	" "	6524	"	"	"	7	"	91.1	.635	6.54	3.74	2.14	30.23	21.6	.022	.0109	2.02	3.5	"	6.41	.22	9.09
A-629	"	"	"	" I	6511	"	297.5	201.0	7	"	87.7	.595	6.13	3.86	2.20	30.99	18.2	.024	.0115	2.09	4.0	"	6.01	.24	8.71
A-630	"	"	"	" "	6514	"	"	268.0	7	"	90.8	.614	6.32	3.73	2.30	32.43	21.3	.047	.0126	3.73	7.7	"	6.19	.48	9.13
B-355	"	"	"	" II	6517	"	302.5	205.0	8	"	88.2	.601	6.19	3.87	2.39	33.75	18.7	.032	.0136	2.35	5.3	"	6.07	.32	8.85
B-356	"	"	"	" I	6514	"	297.5	268.0	7	"	90.8	.616	6.34	3.73	2.40	33.77	21.3	.037	.0137	2.70	5.8	"	6.21	.36	9.03
					Average						90.0	.615	6.34	3.78			20.5					2.46	6.21		

Sheet 2 Span 14

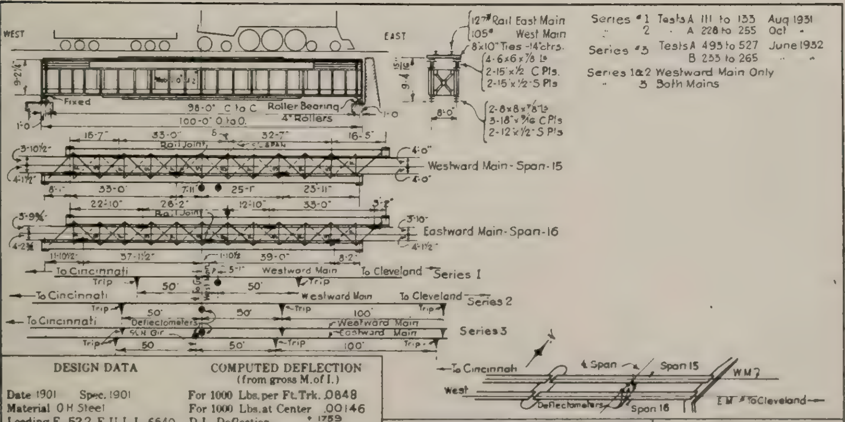
Test				Locomotive					Car		Stat Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No	H.B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist F	Defl (ins) D	E U L L (Kips)	Loaded Frequency n	R P S N	M P H	Dist H (Ft)	Oscil (ins)	Stat Defl H Blow D×N² at Center	Dynamic Magnifier x	Impact γ	D L	L L	Imp	Total
A-627	1	S	W	I62	6915	1070	2028	965	0	-	809	425	437	425	132	1856	-143	034	0028	1213	800	246	428	34	708
A-633	"	"	"	IJ	6954	"	2000	"	0	-	831	425	437	423	133	1876	-111	019	0029	655	45	-	428	19	693
A-632	"	"		I62	6916	"	2028	1415	3	P	871	487	501	414	176	2483	221	029	0051	569	60	"	491	29	766
A-626	"	"	"	IJ	6954	"	2000	-	3	"	864	481	495	409	183	2579	214	011	.0055	200	23	"	485	11	742
B-358	"	"		I62	6915	"	2028	-	3	"	871	487	501	4.14	203	2857	221	022	0068	324	45	"	491	22	759
B-352	"	"	"	IJ	6954	"	2000	-	3	"	864	481	495	409	221	3120	214	.030	0080	375	62	"	485	30	761
				Average							852	464	478	415			±187					246	468		
B-353	1	S	W	L2B	6203	1845	3640	2455	5	F	917	642	661	368	1.61	1985	192	016	.0072	222	25	2.46	648	.16	910

NOTE · Frequencies shown are theoretical frequencies without damping, Actual Frequencies are about 99.8% of above

DL Deflection = 2442

Deflection per 1000# per ft = .0973"

Stress per 1000# per ft = 980#



Series #1 Tests A 111 to 133 Aug 1931
" 2 " A 228 to 255 Oct "
Series #3 Tests A 493 to 527 June 1932
B 233 to 265 " "
Series 1&2 Westward Main Only
" 3 Both Mains

DESIGN DATA

Date 1901 Spec. 1901
Material O H Steel
Loading E-52.2 E.U.L.L. 6640
Flange Stress D.L. • 2400 o 2370
(Tens. N. Sec.) L.L. 7770
Imp. 740
Total • 10910 o 10880
Gross M. of I. at Center 835100
Weight Steel per Ft. 1645
Weight Deck per Ft. • 430 o 410
Total per Ft. • 2075 o 2055
Total for Span • Span 16 • 207500
o Span 15 o 205500

COMPUTED DEFLECTION
(from gross M. of I.)

For 1000 Lbs. per Ft. Trk. .0848
For 1000 Lbs. at Center .00146
D.L. Deflection • .1759 o .1742
D.L. Frequency • 8.21 o 8.26

COMPUTED FROM TESTS
(using Aver. M. of I. 736560)

Deflec. 1000 Lbs. per Ft. Trk. .0961
Deflec. 1000 Lbs. at Center .00166
Deflec. D.L. • .1994 o .1975
Frequency D.L. • 7.75 o 7.72

$$\frac{\text{Average Observed M. of I.}}{\text{Comp. Gross M. of I.}} = .882$$

LOCOMOTIVES USED IN TESTS

Class of Engines	K3J R L	K5P (I)	K5Q	K5B (I)	K5B (II)	K5B (III)	J1D		J1B	
Engines per class	2	4	3	1	3	6	10		1	
Tests per Class	5	6	5	1	9	10	33		1	
Class of Engines	G6c	G6 M	H5La III	H9-a III	H10A II	H10A III	H10B I	H10B II		
Engines per class	1	1	1	1	7	3	5	2		
Tests per Class	6	2	7	3	16	5	9	2		

SPANS 15&16

Bridge 205 Cincinnati Div
East Spans East & West Mains
100 Deck Plate Girder
Single Track Skew

Fig. 54

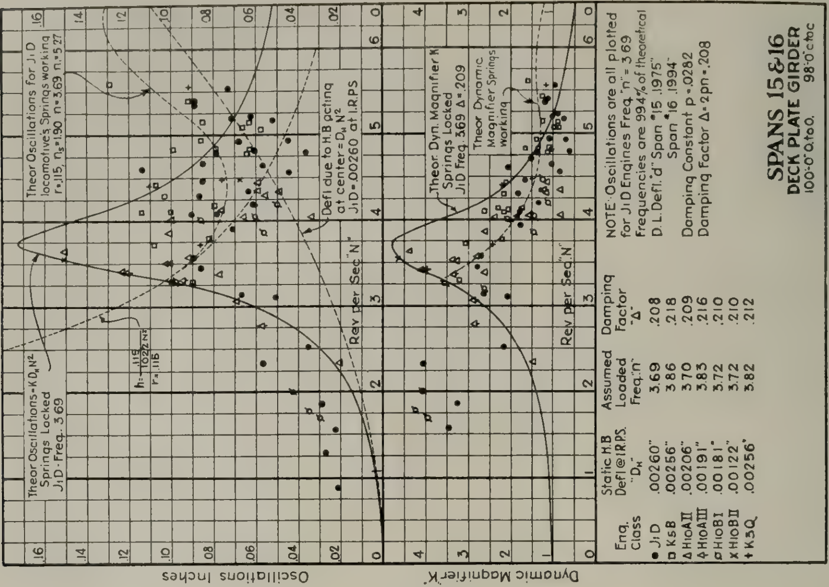


Fig. 55

TABLE XXIX

BR No 205 CINCINNATI-DIV. 100'-0" DP GIRDER WESTWARD MAIN — Sheet 1 Span 15

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R.P.S "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-236	2	S	W	J1E	6629	1671	3515	2220	5	P	820	.646	673	3.68	503	71.02	138	.057	.0650	0.88	88	237	773	68	1078
A-120	1	S	W	J1D	6609	1690	3530	2120	8	P	820	.620	6.45	3.74	089	1249	138	.021	.0021	1000	34	237	742	.25	1004
A-231	2	"	"	"	6610	"	"	2060	11	"	820	617	642	375	128	1808	138	027	0043	628	44	"	739	33	10.09
A-119	1	"	E	"	6619	"	"	2120	10	"	820	611	636	376	157	2213	138	.022	.0064	344	3.6	"	732	.26	995
A-133	1	"	W	"	8224	"	"	2120	6	"	820	.635	661	370	1.86	2745	138	.029	0090	322	46	"	760	.35	1032
A-115	1	"	"	"	6615	"	"	1830	6		820	.613	638	375	233	3291	138	.057	.0141	404	93	"	734	68	1039
A-242	2	"	"	"	6616	"	"	2160	10	"	820	625	650	3.72	251	3595	138	035	0164	213	56	"	748	.42	1027
A-509	3	"	"	"	6612	"		2120	12	"	820	640	666	3.69	310	4370	138	.051	0250	204	80	"	766	.61	1064
B-264	3	"	"	"	6609	"	"	1740	11	"	820	.616	641	3.75	314	4430	138	.067	0256	261	109	"	737	.80	1054
A-512	3	"	"	"	6618	"	"	2125	6	"	820	.641	667	3.69	328	4626	138	100	.0280	357	156	"	7.67	120	1124
A-129	1	"	"	"	6609	"	"	2085	10	"	820	625	650	372	3.45	4869	138	086	.0310	2.77	138	"	748	1.03	1088
A-228	2	"	"	"	6616	"	"	2160	8	"	820	.620	645	374	357	50.39	138	090	0331	272	145	"	742	107	1086
B-242	3	"	"	"	6612	"	"	2120	10	"	820	629	659	372	407	5739	138	091	.0430	212	145	"	758	110	1105
A-113	1	"	"	"	6602	"	"	2120	10	"	820	.622	648	373	408	5758	138	078	.0433	180	125	"	745	.93	10.75
B-258	3	"	"	"	6616	"	"	212.5	10	"	820	.662	689	365	430	6066	138	.087	.0481	181	131	"	793	103	1133
A-238	2	"	"	"	6615	"	"	2245	8	"	820	.607	632	377	455	6420	138	.044	0538	082	72	"	727	.53	1017
A-493	3	"	"	"	6618	"	"	2125		"	820	.613	638	375	460	6485	138	114	0550	207	186	"	7.34	1.37	1108
A-248	2	"	"	"	6610	"	"	2125	[illegible]	"	820	.653	680	366	464	6556	138	057	.0560	102	87	"	783	.68	10.88
B-245	3	"	"	"	6616	"	"	2125	6	"	82.0	.642	668	369	466	6564	138	085	.0565	150	132	"	769	1.02	1108
B-262	3	"	"	"	6612	"	"	2065	5	"	820	.641	6.67	369	482	6798	13.8	.061	.0605	101	95	"	767	.73	10.77
A-517	3	"	"	"	6609	"	"	2195	5	"	820	.644	670	368	5.19	7225	138	071	0701	101	110	"	771	.85	10.93
A-252	2	"	"	"	6615	"	"	212.0	9	"	820	.681	709	361	5.21	7347	138	.062	.0706	088	91	"	8.16	74	1127
A-246	2	"	"	"	8225	"	"	2120	5	"	820	.657	684	366	5.35	75.5	138	089	.0745	119	135	"	787	1.06	1130

Sheet 2 Span 15

Test No.	Series	Girder	Direc of Movement	Locomotive Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist "P"	Stat L L Defl Defl (ins) D	E U L L (Kips)	Loaded Frequency n	Speed R P S "N"	Speed M P H	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow $D_n N^2$ at Center	Dynamic Magnifier K	Impact γ	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A-118	1	S	W	J1D	6619	1690	3530	2100	8	P	820	.630	656	371	537	7575	138	089	.0751	118	141	237	755	106	1098
A-498	3	-	-	-	6617	-	-	2165	5	..	820	605	628	378	5.54	7811	15.8	075	.0800	0.91	121	-	723	87	1047
				Average 24 Tests							820	631	657	371			138					237	756		
A 232	2	S	W	K5B III	6539	1560	3020	113.0	5	P	810	.559	5.82	394	328	4630	128	.078	0243	321	139	237	670	.93	1000
A-254	2	-	..	-	6533	-	..	1210	8	-	810	.585	610	388	3.71	5229	128	.094	0311	302	161	-	702	113	1052
A-235	2	-	-	-	6533	-	..	1380	8	..	810	.583	607	388	3.77	5318	128	071	.0322	220	122	·	699	85	0 21
A-245	2	-	-	K5B I	6512	..	2975	1920	8	-	86.0	.537	5.60	398	409	5778	178	099	0378	262	184	·	645	119	1001
A-497	3	-	-	K5B III	6538	-	302.0	144.0	7	-	810	550	573	397	428	6030	128	090	0414	218	164	..	660	108	1005
A-516	3	-	-	..	6532	-	-	1440	7	-	810	576	600	390	442	6225	128	.093	0442	210	161	·	691	111	1039
B-265	3	-	-	K5B II	6520	-	-	2050	–	-	86.4	572	596	389	479	6760	182	069	.0519	133	121	·	686	82	1005
A-117	1	-	-	K5B III	6531	-	-	1480	8	-	810	579	603	389	483	6818	128	086	.0528	163	148	·	694	103	1034
B-247	3	-	-	K6B II	6520	-	-	2140	6	-	864	582	606	387	493	6956	182	.075	0550	136	129	·	698	90	1025
A-132	1	-	-	K5B III	6531	-	-	1380	8	-	810	615	640	381	538	7575	128	080	0654	1.22	130	-	737	.96	1070
				Average 1 Tests K5B I							860	.537	560	398			178					237	645		
				"	2 -	K5	B II				864	.577	601	388			18.2					237	692		
				"	7 -	K5	B III				810	578	602	3.90			128					237	695		
B-260	3	E	W	K3Q	6491	1645	2955	164.0	7	P	850	.594	619	384	371	5237	174	.085	0352	242	143	237	712	1.02	10.51
A-239	2	-	..	-	6491	-	·	1405	8	-	85.4	.584	608	387	4.40	6215	178	.108	.0496	218	185	·	699	129	1065
A-250	2	..	-	-	6490	-	-	1710	7	-	858	.584	608	387	447	6313	182	.075	0511	147	128	-	699	90	1026
B-249	3	..	..	..	6497	-	-	1565	–	-	850	.603	628	383	555	7825	174	.090	.0788	1.14	149	-	723	108	1068
					Average 4 Tests						853	591	615	385			177					237	708		

Sheet 3 Span 15

Test No	Series	Girder	Direc of Movement	Locomotive Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist "P"	Stat L L Defl Defl (ins) D	E U L L. (Kips)	Loaded Frequency 'n'	Speed R P S "N"	Speed M P H	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow $D_n N^2$ at Center	Dynamic Magnifier K	Impact γ	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A-131	1	S	W	K3P I	6476	2075	2802	1345	5	P	850	.544	567	397	308	4343	175	073	0305	239	13.4	237	653	88	978
A-515	3	-	·	..	6477	..	-	1475	7	-	840	.551	5.74	396	325	4595	165	090	.0340	265	163	-	660	108	1005
A-510	3	-	-	-	6480	-	-	1480	7	-	83.5	565	588	392	3.41	4820	155	.109	0375	290	193	-	677	131	1045
B-243	3	-	..	-	6478	-	-	1610	8	-	840	.554	577	395	472	6652	165	.112	0718	156	202	..	664	134	1035
					Average 4 Tests						84.1	553	5.76	395			166					237	663		
B-246	3	S	W	K3L	6474	1600	2740	1590	7	P	85.8	.512	533	406	299	4224	182	.048	0244	197	94	237	613	58	908
A-244	2	-	·	K3J	6459	-	..	146.0	8	..	862	560	5.84	392	3.21	43.77	184	067	.0258	259	12.0	-	671	80	988
A-495	3	-	-	-	..	-	-	147.5	8	-	862	.554	577	394	3.54	4945	186	101	.0313	323	182	·	664	121	1022
					Average 3 Tests						860	542	5.65	397			18.4					237	6.50		
A-230	2	S	W	H10B I	223	1188	3345	2190	33	F	840	570	594	376	171	1910	198	021	.0053	396	37	237	694	26	957
A-112	1	-	-	-	221	-	-	2155	74	-	840	553	.576	381	319	3590	198	.048	0184	260	87	-	663	58	958
A-511	3	-	-	-	226	-	..	1950	69	-	840	616	642	366	3.28	3686	198	.069	0195	354	112	·	739	83	1059
A-121	1	-	·	H10B II	330	803	-	2020	–	-	840	563	586	378	355	3982	200	.071	.0154	460	126	-	675	85	997
A-494	3	-	·	H10B I	214	1188	-	1790	76	·	840	608	633	368	386	4342	198	.039	0270	144	64	-	728	47	1012
B-248	3	-	-	-	224	·	·	1860	65	·	840	609	634	368	401	4506	198	060	0291	206	99	·	729	72	1038
A-128	1	-	-	-	214	-	·	1860	39		840	557	580	380	404	4546	198	042	0295	142	75	..	667	50	954
A-251	2	·	-	-	214	·	·	2125	35	..	840	560	583	379	419	4712	198	035	0317	110	62	-	671	42	950
A 240	2	·	·	H10B II	322	·	-	2220	30	-	840	560	583	379	447	5028	200	032	0258	124	58	·	671	38	946
					Average 9 Tests						840	577	601	374			19.8					237	691		

Sheet 4 Span 15

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_h N^2$ at Center	Dynamic Magnifier "k"	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips)		No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H	Dist "H" (Ft.)	Oscil (ins)				DL	LL	Imp	Total
							Eng	Tender																	
A-233	2	S	W	H10A II	151	1390	335.0	218 0	59	F	84 8	.597	622	3.75	2 33	2633	18 1	.016	.0112	1 43	2.7	2 37	716	.19	9.72
A-234	2	"	"	H10A III	178	1290	"	185.0	121	"	84.2	.573	5.97	3.81	2.77	31 10	16.9	042	.0147	2.86	73	"	687	50	9.74
A-265	2	"	"	"	178	1290	"	204.5	121	"	842	.625	6 51	3.69	3.05	34.22	16.9	.051	.0177	2 88	8.2	"	7.50	.61	10 48
A-247	2	"	"	"	170	"	"	222 5	68	"	84 2	.636	6.63	366	3.31	37.20	16.9	.070	.0209	3.35	11 0	"	764	.84	10 85
B-263	3	"	"	H10A II	156	1390	"	146.5	79	"	84.8	.572	5.96	3.81	3.37	37.89	18.1	.061	.0234	2 61	10 6	"	6 86	.73	9 96
A-229	2	"	"	H10A III	171	1290	"	214.0	69	"	84.2	.627	6.53	3.68	3.41	38 30	16 9	.089	.0222	4 00	14 2	"	752	1 07	10 96
B-244	3	"	"	H10A II	151	1390	"	210.5	31	"	84.8	.616	6.42	3.71	3.56	40.03	18 1	.073	.0261	2 80	11.8	"	739	.87	10 63
A-494^{X}	3	"	"	"	160	"	"	206.0	76	"		.625	6.51	3.69	3.86	4342		.080	0308	2 59	12 8	"	750	.96	10 83
A-514	3	"	"	"	137	"	"	204.0	51	"	84.8	.606	6.31	3.73	4.02	45.14	18.1	.079	.0332	2 38	13 0	"	727	95	10 59
A-116	1	"	"	H10A III	170	1290	"	197.0	55	"	84.2	.599	6.24	3.75	4 04	4546	16 9	.057	.0312	1.83	9.5	"	7.19	.68	10.24
A-116^{X}	1	"	"	H10A II	156	1390	"	197.0	55	"		.563	5.86	3 84	4 04	4546		.027	.0337	0.80	4 8	"	6 75	.32	9 44
A-130	1	"	"	"	154	"	"	190 0	58	"	84 8	.588	6 12	3.78	4 04	4546	18 1	.052	.0337	1 54	8 8	"	7.05	.62	10 04
B-261	3	"	"	"	152	"	"	226 5	32	"	84 8	.610	6 35	3.72	4.11	46.20	18.1	.061	.0349	1 75	10 0	"	731	.73	10.41
A-243	2	"	"	"	151	"	"	194 5	50	"	84.8	.580	6.04	3.79	4.29	48 18	18 1	.044	.0380	1.16	76	"	6.04	.46	8 87
A-114	1	"	"	"	152	"	"	181.0	65	"	84 8	.553	5 76	3.86	4.33	48.70	18.1	.031	.0387	0 80	5.6	"	6 63	.37	9.37
A-114^{X}	1	"	"	"	160	"	"	181 0	65	"		.586	6.10	3.78	4 33	48.70		.047	.0387	1 21	8.0	"	7.02	.56	9 95
A-253	2	"	"	"	151	"	"	185.0	39	"	84 8	.605	6 30	3.73	4 44	50.00	18.1	.047	.0407	1.15	78	"	725	56	10 18
					Average 17 Tests						84 6	.598	623	3.75			17.7					2 37	7.17		

X Trailing Engine in Double header

Sheet 5 Span 15

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_h N^2$ at Center	Dynamic Magnifier "k"	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips)		No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
							Eng	Tender																	
A-123	1	S	W	H5LA III	6147	2090	277.8	132.0		F	84 2	.492	5.12	4 07	1.57	1763	18.0	.020	.0080	2 50	4 1	2.37	5 89	.24	8.50
A-125	1	"	"	"	6147	"	"	"		"	84.0	.525	5.48	3.97	2.09	23.51	17 8	.021	.0140	1 50	4.0	"	6.31	.25	8.93
A-124	1	"	"	"	6147	"	"	"		"	84 4	.525	5.48	3 97	2.25	25.25	18.2	.021	.0163	1 29	4.0	"	6 31	.25	8.93
A-496	3	"	"	H50 III	6710	"	282.2	127.0	20	"	82.6	.535	5.58	3.95	2.76	31.05	16.4	.045	.0245	1.84	8.4	"	642	.54	9.33
A-126	1	"	"	H5LA III	6147	"	277.8	132.0		"	84.3	.513	5.35	4.01	2.89	32.47	18.1	.042	.0269	1.56	8.2	"	6.16	.50	9.03
A-127	1	"	"	"	6147	"	"	"		"	84 2	.513	5 35	4.01	2 91	32.65	18.0	.069	.0272	2.54	13 4	"	6 16	83	9 36
A-513	3	"	"	H50 III	6710	"	282.2	130.0	9	"	82.8	.550	5.73	3.91	3.03	34.09	16.6	.036	0295	1 22	6.5	"	6.60	.43	9.40
A-241	2	"	"	H5LA III	6147	"	277.8	135.0	12	"	84.1	.525	5.48	3.97	3.18	35.85	17.9	.078	.0325	2 40	14.8	"	6.31	.94	9.62
A-111	1	"	"	"	6147	"	"	134.0	9	"	84.2	.505	5.27	4.03	3.22	36.25	18.0	078	.0334	2.33	15.4	"	6.07	.94	9.38
					Average 9 Tests						83.8	.520	5.43	3.99			17.6					2.37	6.25		
B-259	3	S	W	G6C	6734	1660	234.0	126 0	3	F	78.0	536	5.59	3.98	2.77	31.15	11.0	.037	.0196	1.89	5.9	2.37	6.40	.44	9.21
A-237	2	"	"	G6N	6789	"	236 0	132.0	14	"	78.0	.474	4.94	4.15	3.06	34.35	11.0	.052	.0240	2.17	11.0	"	5.69	.62	8.68
A-249	2	"	"	"	6789	"	"	130.0	5	"	78.0	.490	5.10	4.11	3.40	38.20	11.0	.096	.0295	3.25	19.6	"	5.87	1.15	9.39
B-241	3	"	"	G6C	6734	"	234.0	130.0	5	"	78.0	.531	5.53	3.99	3.47	39.04	11.0	.098	.0307	3.19	18.5	"	6.37	1.18	9.92
				Average 4 Tests							78.0	.508	5.29	4.05			11.0					2.37	6.09		

NOTE:- Tender weights are estimated actual from train sheets and coal reports

TABLE XXX

BR. No. 205 CINCINNATI DIV 100'-0" D.P. GIRDER - EASTWARD MAIN

Sheet 1 Span 16

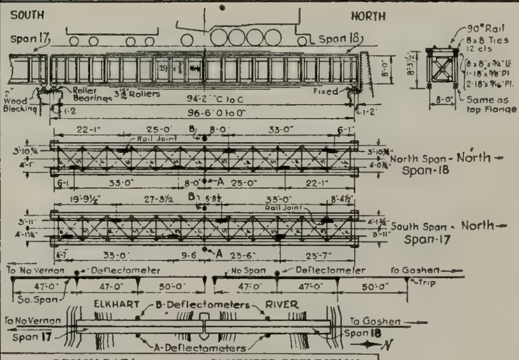
Test		Girder	Direc of Movement	Locomotive					Cars		Stat'l Defl		EULL (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat. Defl H Blow D_H N² at Center	Dynamic Magnifier K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Tender	No	Kind	at Dist "P"	Defl (ins) D			R P S "N"	M P H	Dist "H" (Ft)	Oscil (ins)				D L	L L	Imp	Total
A-519	3	N	E	J1D	6609	1690	3530	214.5	6	P	82.3	.647	674	366	3.94	5550	141	.071	0403	176	110	240	775	.85	11.00
A-499	-	-	-	-	6617	-	"	-	6	-	823	639	665	368	419	59.02	141	061	.0456	1.34	9.6	-	7.65	73	1078
B-251	-	-	-	-	6616	-	"	2190	8	-	823	645	671	366	434	6124	141	063	.0490	1.29	9.4	-	7.72	.73	1085
A-520	-	-	-	-	6618	-	-	2145	9	"	823	620	646	3.72	446	6292	141	085	.0518	164	13.7	-	7.43	1.02	1085
A-527	-	-	"	-	6616	-	-	-	10	-	823	.604	629	3.76	479	67.54	14.1	.079	.0597	132	126	-	724	.91	1055
B-257	-	-	-	-	6612	-	-	2190	11	-	823	.605	630	3.76	480	67.66	141	.036	.0600	0.60	6.0	-	725	.43	10.08
A-507	-	-	-	-	6612	"	-	2145	9	-	823	.608	6.33	374	493	6950	141	.044	0633	0.70	72	-	7.29	53	1022
A-500	-	-	-	-	6618	"	-	-	8	-	823	.635	6.61	368	493	6951	141	068	.0633	1.07	10.3	-	7.60	78	1078
B-240	-	-	-	-	6612	-	-	-	10	-	823	.603	628	376	516	7275	14.1	.052	.0692	0.75	8.6	-	723	62	10.25
					Average 9 Tests						823	.623	649	371			141					240	746		
B-250	3	N	E	K5B II	6521	1690	302.0	207.0	6	P	87.6	600	625	385	4.08	5747	194	078	.0376	2.07	13.0	2.40	7.20	.92	10.52
A-522	-	-	"	K5B III	6539	"	-	156.0	5	"	823	.542	565	386	411	5801	141	.087	.0382	2.28	161	-	650	103	993
B-233	-	"	"	K5B II	6515	-	-	205.0	6	-	882	600	625	385	417	58.76	200	.069	0393	176	110	-	720	80	10.40
B-252	-	-	-	-	6520	-	-	223.0	5	-	885	591	6.15	3.87	4.79	6749	203	056	.0620	108	9.5	"	7.08	67	1015
A-524	-	"	"	-	6515	-	-	2070	5	-	87.0	.575	599	390	481	6784	18.8	.055	.0525	1.05	96	"	6.89	66	9.95
B-234	-	-	-	-	6520	"	-	205.0	8	-	87.6	577	601	390	5.05	71 14	19.4	.050	0578	0.87	87	-	691	.60	991
B-237	-	-	-	-	6521	"	-	214.5	-	-	87.2	551	574	397	507	71 47	19.0	057	.0582	098	103	-	6.60	.68	968
A-504	"	-	-	-	6515	-	-	214.5	5	-	87.2	.582	606	388	5.13	7227	19.0	.055	0596	0.92	94	-	697	.66	10.03
A-501	-	-	-	K5B III	6532	-	"	1560	5	-	82.3	.537	559	386	513	72 36	14.1	.074	.0596	1.24	138	-	6.43	.89	972
B-235	-	-	-	-	6540	-	-	1560	5	-	823	.537	5.59	386	6.58	78.64	141	.112	.0706	159	20.9	-	6.43	134	1017
				Average 7 Tests K5B II							876	.582	606	3.88			19.4					240	697		
					" 3	"	K5B III				823	.539	5.62	386			14.1					2.40	646		

Sheet 2 Span 16

Test		Girder	Direc of Movement	Locomotive					Cars		Stat'l Defl		EULL (Kips)	Loaded Frequency n'	Speed		Hammer Blow		Stat Defl H Blow D_H N² at Center	Dynamic Magnifier K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Tender	No	Kind	at Dist "P"	Defl (ins) D			R P S "N"	M P H	Dist "H" (Ft)	Oscil (ins)				D L	L L	Imp	Total
B-254	3	N	E	K3Q	6497	1645	2955	1520	5	P	850	.551	5.74	387	469	6616	174	085	.0562	151	154	240	661	102	1003
A-523	3	N	E	K3PI	6477	2075	2802	1565	-	P	852	582	606	388	336	4750	177	103	0364	283	177	240	697	123	1060
B-236	3	"	-	"	6477	-	-	"	9	-	840	554	576	395	406	5724	165	103	.0530	194	186	-	663	123	1026
					Average 2 Tests						846	568	591	391			171					240	680		
A-502	3	N	E	K3J	6459	1600	2740	1540	6	P	858	560	583	392	318	4476	182	067	.0253	215	120	240	671	80	991
B-253	3	"		K3L	6474	"	"	1450	5	"	856	554	577	394	392	5533	180	101	0384	263	182		665	121	10.26
					Average 2 Tests						857	557	580	393			181					240	668		
A-508	3	N	E	H10BI	214	1188	334.5	2010	81	F	850	642	668	370	178	2003	208	024	.0057	421	37	240	769	29	1038
A-521	3	-	-	-	226	-	-	-	84	-	850	606	631	378	200	2244	208	029	.0072	403	48	-	726	35	0 01
					Average 2 Tests						850	624	650	374			208					240	748		
A-505	3	N	E	H10AII	135	1390	3350	2255	43	F	857	652	678	369	340	3824	190	097	0238	407	149	240	781	116	1137
B-256	3	-		"	154	-	-	2010	50	-	857	642	668	372	350	3936	190	082	0253	324	128	"	768	98	1106
A-526	-	-	-	-	156	-	-	2210	53	-	857	648	675	370	351	3947	190	085	0254	334	131	-	777	105	1120
B-239	-	-	-	-	135	-	-	2095	50	-	857	611	636	378	363	4081	190	.119	0272	438	.95	-	732	143	1115
					Average 4 Tests						857	638	664	372			190					240	764		
A-518	3	N	E	H50III	6710	2090	2822	1520	11	F	830	608	623	399	324	3642	168	046	0338	136	76	240	717	54	1011

Sheet 3 Span 16

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H.	Dist "H" (Ft)	Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "k"	Impact %	DL	LL	Imp	Total
A-525	3	N	E	G6c	6734	1660	2340	1240	21	F	820	.505	526	406	204	2291	150	.018	.0106	170	36	240	605	.22	8.67
A-506	3	-	"	"	6734	"	-	1230	19	"	820	.478	498	4.14	206	23.11	15.0	.024	.0108	222	50	"	5.73	.29	8.42
B-238	3	-	"	"	6734	"	"	1275	20	-	820	493	514	4.16	209	23.51	150	.030	0111	270	61	"	592	.36	868
B-255	3	-	"	"	6734	"	"	122.0	16	-	82.0	.502	523	407	222	24.87	150	.030	.0126	238	6.0	"	602	36	878
				Average	4	Tests					820	.495	515	409			150					240	5.93		



South Span #17 {Tests A- 635 to 651 Aug 1932
" B 371 to 387 " "
North Span #18 {Tests A- 652 to 661 " "
" B 388 to 397 " "

DESIGN DATA

Date 1900 Spec. 1900
Material O.H Steel
Loading E- 52.4 E.U.L.L. 6830
Flange Stress (Tens.N.Sec.) D.L. 2300
L.L. 9530
Imp. 920
Total 12750
Gross M.of I.at Center 558510
Weight Steel per Ft. 1165
Weight Deck per Ft. 480
Total per Ft. 1645
Total for Span 158800

COMPUTED DEFLECTION
(from gross M.of I.)

For 1000 Lbs.per Ft.Trk. .1144
For 1000 Lbs.at Center .00196
D.L. Deflection .1915
D.L. Frequency 7.68

COMPUTED FROM TESTS
(using Aver.M.of I. 498190)

Deflec.1000 Lbs.per Ft.Trk. .1282
Deflec.1000 Lbs.at Center .00220
Deflec.D.L. .2147
Frequency D.L. 7.32

$\frac{\text{Average Observed M.of I.}}{\text{Comp.Gross M.of I.}} = .892$

LOCOMOTIVES USED IN TESTS

Class of Engines										
Engines per class										
Tests per Class										
Class of Engines		H6A	H10A II							
Engines per class		1	1							
Tests per Class		18	28							

SPANS 17 & 18
Bridge 119 Michigan Div.
North & South Spans-Single Track
96'-6" Deck Plate Girders.

Fig. 56

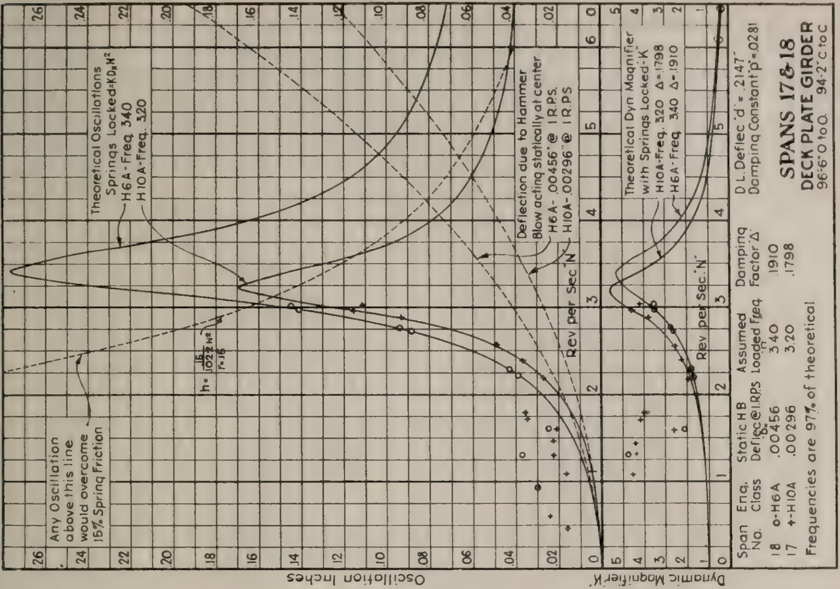


Fig. 57

TABLE XXXI

BR. No. 119 MICHIGAN DIV. 96'-6" D.P. GIRDER SOUTH SPAN

Sheet 1 Span 17

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1 RPS.	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist 'p'	Stat L L Defl Defl (ins) 'D'	E U L L (Kips)	Loaded Frequency 'n'	Speed R.P.S. 'N'	Speed M.P.H.	Hammer Blow Dist 'H' (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow Dₙ N² at Center	Dynamic Magnifier 'K'	Impact 'Y'	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A-637	1	E	S	H10AII	81	1390	3350	2315	2	F	7&8	.871	680	3.30	046	521	140	018	.00063	286	21	23	951	.20	12.01
B-373	-	W	-	-	-	-	-	-	-	-	-	.887	691	327	046	521	-	014	.00063	223	16	-	966	15	12 11
A-638	-	E	-	-	-	-	-	229.5	-	-	-	.863	674	332	059	666	-	025	.00103	242	29	-	942	27	11 99
B-374	-	W	-	-	-	-	-	-	-	-	-	.897	700	326	060	669	-	.023	.00107	215	26	-	979	25	12 34
A-636	-	E	-	-	-	-	-	2335	-	-	-	.853	665	332	1.08	12.15	-	.016	.00346	463	19	-	930	.18	1178
B-372	-	W	-	-	-	-	-	-	-	-	-	.879	6.86	329	1.07	12 06	-	.015	.00339	443	17	-	959	16	1205
A-639	-	E	-	-	-	-	-	2275	-	-	-	.867	676	330	130	1458	-	026	.005	5.20	30	-	945	28	1203
B-375	-	W	-	-	-	-	-	-	-	-	-	.867	676	330	130	1463	-	018	.005	3.60	21	-	945	.20	1195
A-641	-	E	-	-	-	-	-	2235	-	-	-	.871	6.80	330	145	1631	-	.023	.00623	3.69	26	-	951	.25	1206
B-377	-	W	-	-	-	-	-	-	-	-	-	.881	687	3.29	146	1645	-	.020	[illegible]	317	23	-	960	22	1212
A-645	-	E	-	-	-	-	-	215.5	-	-	-	879	685	329	160	1797	-	.019	.0076	2.50	22	-	958	.21	1209
B-381	-	W	-	-	-	-	-	-	-	-	-	.863	674	332	159	1787	-	.020	.0075	267	23	-	942	.22	1194
A-649	-	E	-	-	-	-	-	207.5	42	-	-	.843	658	334	173	1940	-	.039	.0088	443	46	-	920	42	1192
B-385	-	W	-	-	-	-	-	-	-	-	-	857	[illegible]	332	1.70	1908	-	.034	.00855	398	40	-	934	.37	12 01
A-640	-	E	-	-	-	-	-	2255	2	-	-	.873	681	3.29	178	2005	-	.044	.0094	468	50	-	952	.48	1230
B-376	-	W	-	-	-	-	-	-	-	-	-	.893	697	3.26	178	2003	-	.031	.0094	330	35	-	974	34	1238
A-643	-	E	-	-	-	-	-	2195	-	-	-	.871	680	3.30	218	2450	-	032	.0141	227	37	-	951	35	1216
B-379	-	W	-	-	-	-	-	-	-	-	-	.865	667	332	218	2445	-	.022	.0141	156	26	-	932	.24	1186
A-642	-	E	-	-	-	-	-	2215	-	-	-	.877	684	3.29	238	2680	-	.040	.0168	238	46	-	956	.44	1230
B-378	-	W	-	-	-	-	-	-	-	-	-	.861	671	332	237	2667	-	035	.0166	211	41	-	938	38	1206
A-646	-	E	-	-	-	-	-	2135	-	-	-	.873	681	3.29	257	2881	-	.054	.0195	277	62	-	952	.59	1241
B-382	-	W	-	-	-	-	-	-	-	-	-	843	658	335	254	2850	-	.043	.0191	225	51	-	920	47	1197
A-644	-	E	-	-	-	-	-	2176	-	-	-	893	697	326	289	3245	-	094	.0247	381	105	-	974	102	1306
B-380	-	W	-	-	-	-	-	-	-	-	-	863	665	332	289	3250	-	[illegible]	.0247	372	109	-	930	101	1261

Sheet 2 Span 17

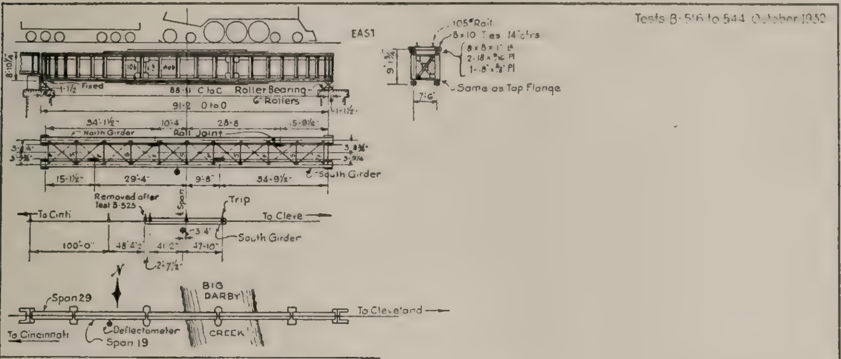
Test No.	Test Series	Girder	Direc. of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1 R.P.S	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No.	Cars Kind	Stat L.L Defl at Dist "P"	Stat L.L Defl Defl. (ins) "D"	E U L L. (Kips)	Loaded Frequency "n"	Speed R.P.S "N"	Speed M.P.H.	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec D.L	L.L.	Imp.	Total
A-647	1	E	S	H10 A II	81	1390	335.0	211.5	2	F	78.8	.879	6.85	3.29	2.96	3320	14.0	.121	.026	4.65	13.6	2.3	9.58	1.30	13.18
B-383	"	W	"	"	"	"	"	"	"	"	"	.851	6.64	3.33	2.95	33.17	"	.117	.0258	4.37	13.8	"	9.28	1.28	12.86
A-648	"	E	"	"	"	"	"	209.5	"	"	"	.879	6.85	3.29	3.04	34.15	"	.116	.0274	4.24	13.2	"	9.58	1.26	13.14
B-384	"	W	"	"	"	"	"	"	"	"	"	.835	6.51	3.35	2.98	33.52	"	.106	.0263	4.03	12.7	"	9.10	1.16	12.56
				Average	East	Girder	14	Tests			78.8	.871	6.79	3.30			14.0					2.3	9.49		
				"	West	"	14	"			78.8	.866	6.75	3.30			14.0					"	9.44		
				"	All	Tests					78.8	.868	6.77	3.30			14.0					"	9.46		

TABLE XXXII

BR. No. 119 MICHIGAN-DIV. 96'-6" D.P. GIRDER NORTH SPAN

Sheet 1 Span 18

Test No.	Test Series	Girder	Direc. of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1 R.P.S.	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No.	Cars Kind	Stat L.L Defl at Dist "P"	Stat L.L Defl Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	Speed R.P.S. "N"	Speed M.P.H.	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec D.L.	L.L	Imp	Total
A 656	1	E	S	H6A	6096	2140	290.8	144.3	2	F	79.6	.730	5.70	3.53	093	1046	16.9	.030	.00394	7.61	4.1	2.30	7.97	.33	1060
A-392	"	W	"	"	"	"	"	"	"	"	"	.736	6.26	3.51	0.93	10.46	"	.030	.00394	7.61	4.1	"	8.75	.36	11.41
A-654	"	E	"	"	"	"	"	147.3	"	"	"	.746	6.18	3.50	1.30	17.42	"	.032	.00768	4.17	4.3	"	8.64	.37	11.31
B-390	"	W	"	"	"	"	"	"	"	"	"	.752	6.14	3.49	1.30	17.42	"	.041	.00768	5.33	5.5	"	8.58	.47	11.35
A-653	"	E	"	"	"	"	"	148.8	"	"	"	.724	6.35	3.54	1.61	1809	"	.024	.0118	2.03	3.3	"	8.88	.29	11.47
B-389	"	W	"	"	"	"	"	"	"	"	"	.734	6.27	3.52	1.61	18.13	"	.026	.0118	2.20	4.2	"	8.77	.37	11.44
A-661	"	E	"	"	"	"	"	145.8	"	"	"	.748	6.16	3.49	2.23	25.10	"	.035	.0226	1.55	4.7	"	8.61	.40	11.31
B-397	"	W	"	"	"	"	"	"	"	"	"	.756	6.10	3.48	2.23	25.04	"	.040	.0226	1.77	5.3	"	8.53	.45	11.28
A-661	"	E	"	"	"	"	"	136.8	"	"	"	.730	6.30	3.53	2.27	25.52	"	.037	.0234	1.58	5.1	"	8.81	.45	11.56
B-397	"	W	"	"	"	"	"	"	"	"	"	.732	6.29	3.52	2.28	25.65	"	.048	0236	2.03	6.6	"	8.79	.58	11.67
A-657	"	E	"	"	"	"	"	142.8	"	"	"	.746	6.18	3.50	2.71	30.46	"	.094	.0334	2.81	12.1	"	8.64	1.05	11.99
B-393	"	W	"	"	"	"	"	"	"	"	"	.746	6.18	3.50	2.75	30.88	"	.082	.0344	2.38	11.0	"	8.64	.95	11.89
A-658	"	E	"	"	"	"	"	141.3	"	"	"	.742	6.21	3.50	2.76	31.05	"	.097	0346	2.80	13.1	"	8.68	1.14	12.12
B-394	"	W	"	"	"	"	"	"	"	"	"	.742	6.21	3.50	2.77	31.13	"	.095	.0349	2.72	12.8	"	8.68	1.11	12.09
A-659	"	E	"	"	"	"	"	139.8	"	"	"	.736	6.26	3.51	2.97	33.43	"	.154	.0401	3.84	21.0	"	8.75	1.84	12.89
B-395	"	W	"	"	"	"	"	"	"	"	"	.734	6.27	3.52	2.98	33.51	"	.128	.0405	3.16	17.5	"	8.77	1.53	12.60
A-660	"	E	"	"	"	"	"	138.3	"	"	"	.732	6.29	3.52	3.02	33.95	"	.151	.0415	3.64	20.7	"	8.79	1.82	12.91
B-396	"	W	"	"	"	"	"	"	"	"	"	.732	6.29	3.52	3.03	34.01	"	.140	.0418	3.35	19.1	"	8.79	1.68	12.77
				Average	East	Girder	9	Tests			79.6	.737	6.18	3.51			16.9					2.30	8.64		
					"	West	"	9	"		79.6	.740	6.22	3.51			16.9					2.30	8.70		
					" All	Tests					79.6	.739	6.20	3.51			16.9					2.30	8.67		



DESIGN DATA		
Date 1924	Spec. 1917	
Material O H Steel		
Loading E-70	E.U.L.L.	9240
Flange Stress	D.L.	2000
(Tens. N. Sec.)	L.L.	8900
	Imp.	7050
	Total	17950
Gross M. of I. at Center		776660
Weight Steel per Ft.		1650
Weight Deck per Ft.		440
Total per Ft.		2090
Total for Span		190500

COMPUTED DEFLECTION (from gross M. of I.)	
For 1000 Lbs. per Ft. Trk.	.0664
For 1000 Lbs. at Center	.00121
D.L. Deflection	.1387
D.L. Frequency	9.21

COMPUTED FROM TESTS (using Aver. M. of I. 705210)	
Deflec. 1000 Lbs. per Ft. Trk.	.0731
Deflec. 1000 Lbs. at Center	.00133
Deflec. D.L.	.1528
Frequency D.L.	8.77
Average Observed M of I. / Comp Gross M. of I.	.908

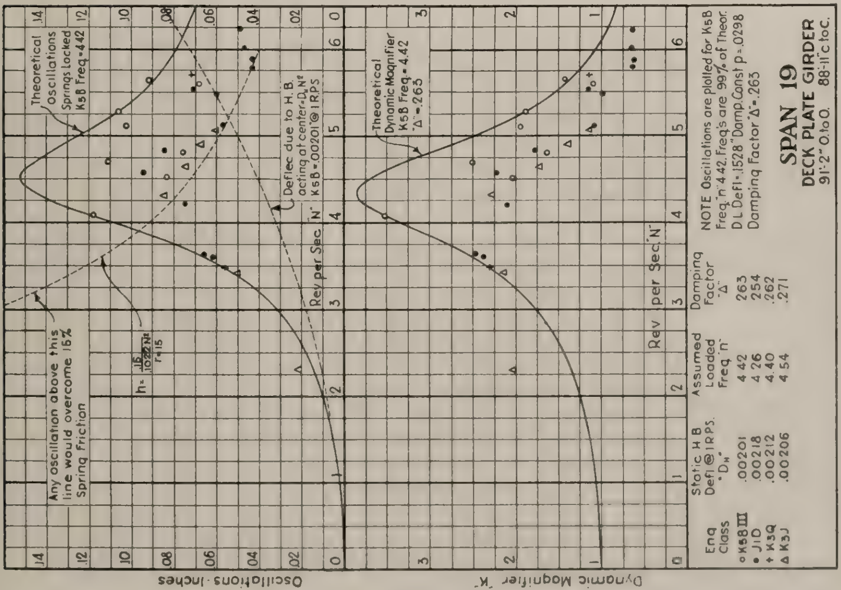
LOCOMOTIVES USED IN TESTS

Class of Engines	K3J K3K K3L	K3Q	K5B (III)	J1D						
Engines per class	2	2	5	5						
Tests per class	6	2	8	12						
Class of Engines	K5LA									
Engines per class	1									
Tests per class	1									

SPAN 19

Bridge 428 Cincinnati Div
2ND Span Single Main
91'-2" Deck Plate Girder

Fig. 58



Eng Class	Static H B Defl @ 1 R.P.S. "D_N"	Assumed Loaded Freq. "n"	Damping Factor "Δ"
○ K5B III	.00201	4.42	.263
● J1D	.00218	4.26	.254
+ K3Q	.00212	4.40	.262
Δ K3J	.00206	4.54	.271

NOTE Oscillations are plotted for K5B Freq. "n" 4.42. Freq's are 99% of Theor. D L Defl = .1528" Damp. Const p = .0298 Damping Factor "Δ" = .263

SPAN 19
DECK PLATE GIRDER
91'-2" O. to O. 88'-11" c to c.

Fig. 59

TABLE XXXIII

BRIDGE No. 428 CINCINNATI DIV. 91'-2" DECK PLATE GIRDER

Sheet 1 Span 19

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L.L. Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow D_N N² at Center	Dynamic Magnifier "k"	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec			
No.	Series			Class	Eng No.	H.B at 1RPS	Weight (Kips)		No	Kind	at Dist. "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H.	Dist "H" (Ft.)	Oscil (ins)							
							Eng	Tender														D.L.	L.L.	Imp.	Total
B-538	I	S	E	J1D	6608	1691	353.0	263.8	8	P	82.8	.523	7.16	4.26	3.60	50.95	19.1	.066	.0280	2.36	12.6	2.00	6.86	0.87	9.73
B-542	"	"	W	"	6618	"	"	265.9	5	"	"	.505	6.92	4.32	3.64	51.45	"	.071	.0286	2.48	14.1	"	6.62	0.93	9.55
B-531	"	"	E	"	6618	"	"	266.8	8	"	"	.503	6.89	4.33	4.22	59.52	"	.081	.0385	2.10	16.1	"	6.60	1.06	9.66
B-535	"	"	W	"	6614	"	"	265.9	5	"	"	.534	7.31	4.24	4.57	64.50	"	.101	.0452	2.24	19.0	"	7.00	1.32	10.32
B-519	"	"	W	"	6612	"	"	265.9	5	"	"	.558	7.64	4.16	4.84	68.26	"	.090	.0508	1.77	16.2	"	7.32	1.18	10.50
B-544	"	"	E	"	6616	"	"	265.6	10	"	"	.491	6.73	4.37	5.12	72.14	"	.061	.0568	1.07	12.4	"	6.44	0.80	9.24
B-524	"	"	"	"	6612	"	"	261.7	8	"	"	.533	7.30	4.24	5.48	77.20	"	.064	.0650	.98	12.0	"	6.98	0.84	9.82
B-537	"	"	"	"	6616	"	"	265.6	10	"	"	.504	6.90	4.33	5.53	77.99	"	.076	.0662	1.15	15.1	"	6.61	1.00	9.61
B-530	"	"	"	"	6614	"	"	265.6	9	"	"	.491	6.73	4.37	5.80	81.82	"	.046	.0730	.63	9.4	"	6.44	0.60	9.04
B-521	"	"	"	"	6608	"	"	265.6	9	"	"	.509	6.97	4.31	5.88	83.35	"	.046	.0749	.61	9.1	"	6.67	0.61	9.28
B-518	"	"	W	"	6618	"	"	264.2	5	"	"	.519	7.16	4.27	6.01	84.75	"	.051	.0782	.65	9.9	"	6.80	0.67	9.47
B-516	"	"	E	"	6614	"	"	261.7	8	"	"	.473	6.48	4.43	6.24	87.94	"	.053	.0843	.63	11.2	"	6.20	0.70	8.90
				Average 12 Tests							82.8	.512	7.01	4.30			19.1					2.00	6.71		
B-534	I	S	E	K5BIII	6532	1560	303.0	176.7	5	P	78.9	.428	5.86	4.58	4.08	57.60	15.2	.118	.0335	3.52	27.6	2.00	5.61	1.55	9.16
B-527	"	"	"	"	6537	"	"	176.7	5	"	"	.453	6.20	4.49	4.52	63.85	"	.083	.0410	2.02	18.4	"	5.94	1.09	9.03
B-532	"	"	W	"	6537	"	"	172.4	6	"	"	.460	6.30	4.46	4.70	66.40	"	.111	.0445	2.50	24.2	"	6.03	1.46	9.49
B-540	"	"	"	"	6534	"	"	176.8	6	"	"	.475	6.50	4.40	4.81	68.00	"	.076	.0466	1.63	16.0	"	6.22	1.00	9.22
B-541	"	"	E	"	6537	"	"	176.6	5	"	"	.444	6.09	4.52	5.10	72.00	"	.102	.0524	1.95	23.0	"	5.82	1.34	9.16
B-528	"	"	W	"	6535	"	"	178.2	5	"	"	.464	6.35	4.45	5.28	74.50	"	.106	.0561	1.89	22.9	"	6.09	1.39	9.48
B-525	"	"	"	"	6532	"	"	181.9	5	"	"	.475	6.50	4.40	5.60	79.05	"	.068	.0631	1.08	14.3	"	6.22	0.89	9.11
B-517	"	"	"	"	6539	"	"	175.9	5	"	"	.472	6.46	4.42	5.65	79.80	"	.092	.0642	1.43	19.5	"	6.19	1.20	9.39
				Average 8 Tests							78.9	.459	6.29	4.46			15.2					2.00	6.01		

Sheet 2 Span 19

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L.L. Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow D_N N² at Center	Dynamic Magnifier "k"	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec			
No.	Series			Class	Eng No.	H B at 1R.P.S.	Weight (Kips)		No	Kind	at Dist. "P"	Defl. (ins) "D"			R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)							
							Eng	Tender														D.L	L.L	Imp.	Total
B-539	I	S	W	K3Q	6491	1650	295.5	180.8	7	P	80.3	.435	5.95	4.54	3.47	48.92	17.2	.059	.0255	2.31	13.6	2.00	5.70	0.77	8.47
B-522	"	"	"	"	6495	"	"	168.6	4	"	"	.482	6.60	4.37	5.69	80.17	"	.077	.0686	1.12	16.0	"	6.32	1.01	9.33
				Average 2 Tests							80.3	.458	6.27	4.45			17.2					2.00	6.01		
B-526	I	S	W	K3J	6456	1603	274.0	146.7	7	P	78.6	.405	5.54	4.63	2.29	32.25	15.5	.022	.0109	2.02	5.4	2.00	5.31	0.29	7.60
B-536	"	"	E	"	6456	"	"	167.9	8	"	"	.396	5.42	4.67	3.41	48.02	"	.051	.0240	2.12	12.9	"	5.19	0.67	7.86
B-533	"	"	W	"	6457	"		174.7	8	"	"	.434	5.94	4.52	4.30	60.70	"	.086	.0382	2.25	19.9	"	5.69	1.13	8.82
B-520	"	"	E	"	6456	"	"	167.9	5	"	"	.426	5.83	4.55	4.64	65.45	"	.076	.0445	1.71	17.9	"	5.59	1.00	8.59
B-543	"	"	"	"	6457	"	"	167.9	9	"	"	.408	5.58	4.62	4.90	69.15	"	.069	.0496	1.39	16.9	"	5.35	0.91	8.26
B-529	"	"	"	"	6457	"	"	170.2	7	"	"	.428	5.86	4.55	5.05	71.13	"	.061	.0528	1.15	14.3	"	5.61	0.80	8.41
				Average 6 Tests							78.6	.416	5.70	4.59			15.5					2.00	5.45		
B-523	I	S	W	H5LAII	6131	2092	277.8	114.2	32	F	79.2	.418	5.72	4.58	3.74	42.02	17.5	.055	.0378	1.45	13.2	2.00	5.47	0.72	8.19

SPAN NO. 20

A deck girder span 83 ft. long over all, and 80 ft. 8 in. center to center of bearings. See Fig. 60.

The large number of tests at this bridge were made in an effort to determine the cause of the small oscillations. For a great many tests the dynamic magnification was found to be much smaller than was to be expected, and in fact but one or two runs produced oscillations that approached or equalled the theoretical values computed from a normal damping factor. While the oscillations may have been damped by spring action, it is probable that other conditions affected them to a greater extent. The lateral vibration of this girder was unusually noticeable, and there was considerable movement in the piers, which were tall and slender. Our conclusion was that a large part of the energy, from the rotating drivers, was absorbed in moving the structure in a lateral rather than a vertical direction.

From the few undamped oscillations the damping constant was found to be .0324. This is a little high perhaps, but it cannot be far out of line, as the girder is quite deep. The deflection factor is 1.130.

SPAN NO. 21

A deck girder span, 77 ft. 6 in. long over all, and 75 ft. 6 in. center to center of bearings. See Fig. 62.

For some reason, the oscillations in this span do not seem to be damped by locomotive spring action, although they were of such magnitude that spring friction should have been overcome. The theoretical and actual values are in close agreement, as will be seen in Fig. 63.

The damping constant was found to be .0321 and the deflection factor is 1.115.

SPAN NO. 22

A deck girder span, 70 ft. long over all, 68 ft. center to center of bearings. The girders were designed for a concrete deck and ballasted track, but were constructed with an open floor. See Fig. 64.

The track on this bridge is badly off center, and there was some play under the bearings, with considerable lateral vibration. The speeds were quite high, most of the passenger trains running from 80 to 90 m.p.h., and the freight trains up to 70 m.p.h. Most of the oscillations, at the high speeds, have apparently been reduced by damping of some sort, as will be seen from Fig. 65.

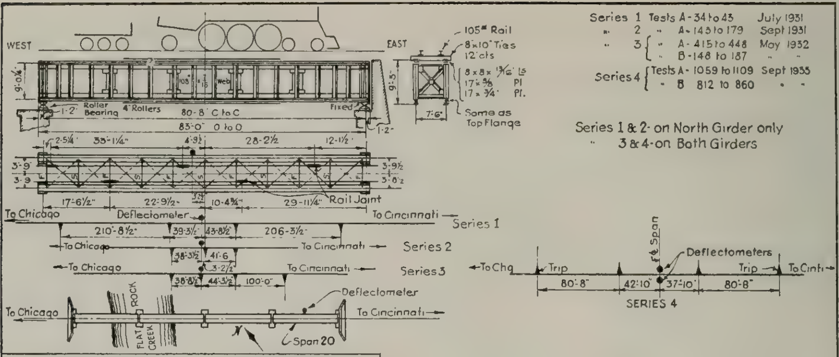
The damping constant was found to be .0350 and the deflection factor 1.096.

SPAN NO. 23

A deck girder 64 ft. 7 in. long over all, and 63 ft. center to center of bearings. See Fig. 66.

This is a light span, and only a few tests were made to check the deflections and actual impact under certain locomotives. There were not enough tests for a reliable determination of the damping constant, but assuming a value of .037, the theoretical values of the oscillations have been computed, and it will be seen from Fig. 67 that they are not far from the few measured values, being higher for speeds at which spring damping apparently was effective.

The substructure at this bridge is not in good condition, the bridge seats being cracked, and the span carried on timber blocking. This makes it difficult to determine the actual deflection factor. The value of 1.033, as given, seems somewhat low.



DESIGN DATA

Date 1910	Spec. 1910	
Material O H Steel		
Loading E-60	E.U.L.L.	8070
Flange Stress	D.L.	1970
(Tens. N. Sec.)	L.L	8290
	Imp.	6520
	Total	16780
Gross M. of I. at Center		638590
Weight Steel per Ft.		1410
Weight Deck per Ft.		510
Total per Ft.		1920
Total for Span		159400

COMPUTED DEFLECTION
(from gross M. of I.)

For 1000 Lbs. per Ft. Trk.	.0556
For 1000 Lbs. at Center	.00113
D.L. Deflection	.1066
D.L. Frequency	10.45

COMPUTED FROM TESTS
(using Aver. M. of I. 565780)

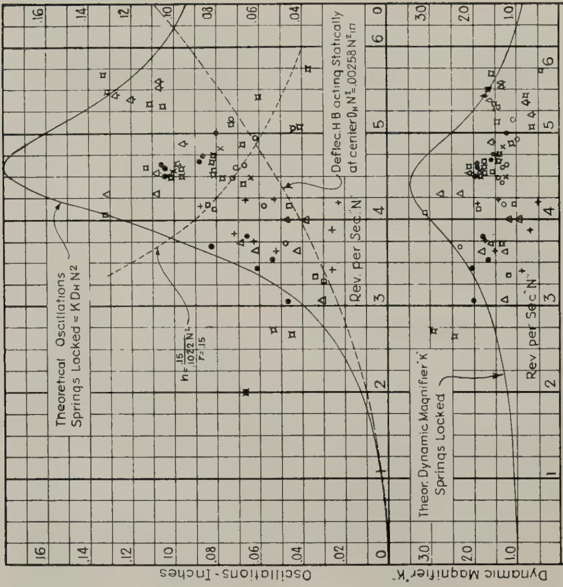
Deflec. 1000 Lbs. per Ft. Trk.	.0627
Deflec. 1000 Lbs. at Center	.00127
Deflec. D.L.	.1203
Frequency D.L.	9.82
$\frac{\text{Average Observed M. of I.}}{\text{Comp. Gross M. of I.}}$	.886

LOCOMOTIVES USED IN TESTS

Class of Engines	K KB	K-N K-O	K3J K3K K3L	K3P II	K3Q	K5/H5LA	K5-B	J1D	J1E	H6A
Engines per Class	3	2	3	1	1	1/1	8	5	1	2
Tests per Class	12	4	10	2	2	7/6	40	15	6	4
Class of Engines	H5L (I)		H6-O II	H7-E II	H7-E III		H7-E V	H10-A I	L2-B	L2D/L2C
Engines per class	1		4	1	1		2	6	5	4/6
Tests per class	4		19	1	2		6	14	11	10/20

SPAN 20
Bridge 378 Chicago Div.
East Span Single Track
83'-0" Deck Plate Girder.

Fig. 60



Class Eng.	H.B 1 R.P.S.	H.B Defl. D_H 1 R.P.S.	Freq. "n"	Damp. Factor "Δ"
o - L2D	2153	.00258	4.46	.289
● - L2C	1854	.00223	4.48	.290
Δ - L2B	1844	.00221	4.48	.290
□ - H10A (I)	1270	.00153	4.48	.290
□ - H10A (II)	1390	.00168		
+ H7E	2455	.00296	4.50	.292
× J1E	1672	.00205	4.51	.292
◇ J1D	1691	.00207	4.53	.293
⌑ K5B	1560	.00189	4.65	.301

The higher measured oscillations of each pair of tests is plotted

NOTE - Oscillations are all plotted for L2D Engines
Freq. "n" = 4.46
Frequencies shown are 98.5% of theoretical freq
D.L. Defl. of Span "d" = .1203
Damp. Constant "p" = .0324
Damp. Factor Δ = 2pn = .289

SPAN 20
DECK PLATE GIRDER
83'-0" o. to o. 80'-0" c. to c.

Fig. 61

TABLE XXXIV

BR No. 378 CHICAGO DIV. 83'-0" DECK PLATE GIRDER

Sheet 1 Span 20

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D			R.P.S. 'N'	M.P.H	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-1088	4	N	W	J1E	6624	1672	351.5	2870	7	P	720	.436	696	459	446	6288	125	.052	.0408	128	119	197	713	.85	1192
B-841	4	S	-	-	-	-	-	-	-	-	72.0	.440	702	457	449	6334	125	.052	.0413	126	118	-	7.20	.85	1002
A-1070	[illegible]	N	-	-	-	-	-	2860	10	-	720	.438	699	458	4.54	6404	125	.049	.0422	116	112	-	716	.80	993
B-823	4	S	-	-	-	-	-	-	-	-	720	.451	7.20	452	454	6406	12.5	.079	0422	187	175	-	738	1.29	10.64
A-1103	4	N	-	-	-	-	-	2870	8	-	720	440	702	457	482	6792	12.5	.043	.0476	.90	9.8	-	720	.71	988
B-856	4	S	-	-	-	-	-	-	-	-	72.0	.433	691	460	483	6816	125	.062	.0478	1.30	143	-	708	101	1006
				Average	3 Test	North	Girder				72.0	.438	699	458			125					197	716		
				-	3 -	South	-				72.0	.441	7.04	457			125					-	722		
B-816	4	S	E	J1D	6619	1691	353.0	191.5	14	P	69.5	.421	6.72	4.61	451	6357	10.0	.067	.0421	1.59	159	197	689	110	996
A-1063	4	N	-	-	6619	-	-	-	-	-	69.6	.417	665	4.63	453	6389	10.0	.087	.0425	204	208	-	682	142	1021
B-852	4	S	W	-	6619	-	-	286.5	11	-	72.3	.457	729	456	4.87	68.63	12.8	077	.0491	157	16.8	-	747	125	1069
A-1099	4	N	-	-	6619	-	-	-	-	-	723	.465	742	4.52	4.88	68.75	128	.063	.0493	128	13.6	-	761	103	1061
A-1060	4	N	-	-	6605	-	-	2870	10	-	72.3	.454	725	457	5.19	7310	128	.035	.0558	.63	7.7	-	743	.57	9.97
A-1085	4	N	-	-	6605	-	-	-	-	-	723	.438	6.99	463	534	7522	12.8	.046	.0590	.78	105	-	716	.75	988
B-838	4	S	-	-	6605	-	-	-	-	-	72.3	.446	711	460	539	7597	128	.096	.0600	1.60	215	-	729	157	10.83
B-822	4	S	-	-	6606	-	-	294.5	-	-	72.3	.467	7.45	451	5.39	75.98	128	.103	0600	172	22.0	-	764	1.68	11.29
A-1069	4	N	-	-	6606	-	-	-	-	-	723	.459	732	455	544	7663	128	.056	.0612	.91	12.2	-	750	.92	10.39
B-851	4	S	-	-	6601	-	-	294.0	-	-	72.3	.457	7.29	456	5.51	77.67	12.8	086	.0628	137	18.8	-	747	140	10.84
A-1098	4	N	-	-	6601	-	-	-	-	-	72.3	.450	718	458	552	77.81	128	.056	.0630	.89	12.4	-	736	.91	10.24
A-1084	4	N	-	-	6603	-	-	-	-	-	723	.441	704		5.55	78.19	128	.035	0637	.55	79	-	722	.57	976
B-837	4	S	-	-	6603	-	-	-	-	-	723	.473	7.55		5.55	78.19	12.8	086	0637	1.35	182	-	774	141	11.12

Sheet 2 Span 20

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D			R.P.S. 'N'	M.P.H	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-1084	4	N	W	J1D	6603	1691	353.0	294.0	10	P	72.3	.441	704	461	555	7819	128	.035	.0637	55	79	197	722	.57	976
B-837	4	S	-	-	-	-	-	-	-	-	72.3	.473	755	450	5.55	7819	128	086	.0637	135	182	-	774	141	1112
				Average 6 Tests	N	Girder	Westward				72.3	451	720	457			128					1.97	7.38		
				- 5	- S	-	-				723	460	734	454			128					-	7.52		
				- 1	- N	-	Eastward				69.5	.417	665	463			100					-	6.82		
				- 1	- S	-	-				695	.421	672	461			10.0					-	689		
B-186	3	S	E	K5	6525	1671	3030	2095	-	P	683	408	652	475	450	6346	89	.073	.0415	176	179	1.97	6.68	120	985
A-447	3	N	-	-	-	-	-	-	—	-	683	.397	634	480	451	6353	89	071	.0418	170	179	-	650	116	9.63
A-143	2	N	W	-	-	-	-	265.0	—	-	70.0	.397	634	466	460	6491	106	043	0435	99	108	-	650	70	917
B-162	3	N	E	-	-	-	-	1975	—		683	.400	639	479	489	6895	89	.035	0490	72	87	-	655	57	909
A-421	3	S	-	-	-	-	-	-	—	-	683	.405	647	477	492	6935	89	048	.0497	96	118	-	663	78	938
B-170	3	N	W	-	-	-	-	265.0	—	-	70.0	295	470	520	555	[illegible]	106	024	0631	.37	81	-	482	39	718
A-429	3	S	W	-	-	-	-	-	—	-	70.0	468	748	437	556	7837	106	059	0634	93	126	-	767	97	10.61
				Average 3 Tests Westward							70.0	387	618	470			106					197	633		
				- 2	- N	Girder	Eastward				683	398	6.35	480			89					-	651		
				- 2	- S	-	-				683	406	648	476			89					-	664		
B-821	4	S	E	K5B III	6531	1560	3020	173.0	[illegible]	P	70.8	406	648	474	199	4104	103	.049	0075	653	.21	1.97	664	.80	941
A 1068	4	N	-	-	6531	-	-	-	-	-	708	.406	648	474	199	4115	103	042	0075	560	103	-	664	.68	929
B-836	4	S	-	K5B I	6505	-	2975	237.5	-	-	694	386	616	483	262	3697	89	.028	0130	215	72	-	631	45	873
A-1083	4	N	-	-	6506	-	-	-	-	-	694	.371	592	490	265	3735	[illegible]	.033	.0133	248	89	-	606	.54	8.57
B 850	4	S	-	-	6506	-		-	5	-	694	404	645	475	270	3810	89	031	.0138	224	77	-	661	51	909
A 1097	4	N		-	6506					-	694	405	647	4.75	272	3830	89	.041	0140	293	101		663	67	927

Sheet 3 Span 20

Test				Locomotive					Cars		Stat L.L. Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net. Sec			
No.	Series	Girder	Direc. of Movement	Class	Eng No.	H. B. at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No.	Kind	at Dist. "P"	Defl. (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency 'n'	R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	D.L.	L.L.	Imp	Total
A-40	1	N	W	K5B I	6506	1560	297.5	265.5	7	P	70.1	.358	5.72	4.97	3.72	52.44	9.6	.035	.0262	1.33	9.7	1.97	5.86	.57	8.40
A-420	3	S	"	"	6509	"	"	258.5	–	"	70.1	.418	6.67	4.69	4.41	62.24	9.6	.049	.0367	1.33	11.7	"	6.84	.80	9.61
B-161	3	N	"	"	6509	"	"	"	–	"	70.1	.415	6.63	4.70	4.42	62.28	9.6	.043	.0370	1.16	10.3	"	6.80	.70	9.47
A-150	2	N	E	"	6513	"	"	182.0	10	"	67.7	.379	6.05	4.87	4.48	63.10	7.2	.056	.0380	1.47	14.8	"	6.20	.92	9.09
A-145	2	N	W	"	6514	"	"	262.5	–	"	70.1	.414	6.61	4.70	4.51	63.60	9.6	.074	.0385	1.92	17.9	"	6.78	1.21	9.96
A-1075	4	N	E	"	6508	"	"	174.5	12	"	67.7	.389	6.21	4.82	4.51	63.56	7.2	.071	.0385	1.84	18.3	"	6.37	1.17	9.61
B-828	4	S	"	"	6508	"	"	"	"	"	67.7	.415	6.63	4.70	4.51	63.56	7.2	.062	.0385	1.61	14.9	"	6.80	1.01	9.78
B-858	4	S	"	"	6508	"	"	"	"	"	67.7	.365	5.83	4.93	4.52	63.70	7.2	.059	.0387	1.53	16.2	"	5.98	.97	8.92
A-1105	4	N	"	"	6508	"	"	"	"	"	67.7	.389	6.21	4.82	4.53	63.82	7.2	.069	.0389	1.77	17.7	"	6.37	1.13	9.47
B-827	4	S	W	"	6514	"	"	258.0	7	"	70.1	.429	6.85	4.65	4.59	64.74	9.6	.071	.0398	1.78	16.5	"	7.02	1.16	10.15
A-1074	4	N	"	"	6514	"	"	"	"	"	70.1	.413	6.60	4.69	4.59	64.75	9.6	.043	.0398	1.08	10.4	"	6.77	.70	9.44
B-185	3	S	"	"	6509	"	"	"	–	"	70.1	.402	6.42	4.76	4.59	64.75	9.6	.083	.0398	2.09	20.7	"	6.58	1.36	9.91
A-446	3	N	"	"	6509	"	"	"	–	"	70.1	.432	6.90	4.63	4.60	64.78	9.6	.062	.0400	1.55	14.4	"	7.07	1.02	10.06
A-168	2	N	E	"	6505	"	"	176.0	9	"	67.7	.401	6.42	4.76	4.68	65.95	7.2	.072	.0414	1.74	17.9	"	6.58	1.18	9.73
A-159	2	N	W	"	6513	"	"	262.5	12	"	70.1	.372	5.94	4.90	4.68	66.03	9.6	.060	.0414	1.45	16.1	"	6.09	.98	9.04
A-1091	4	N	E	"	6508	"	"	167.5	11	"	67.7	.391	6.24	4.80	4.68	66.00	7.2	.072	.0414	1.74	18.4	"	6.40	1.18	9.55
B-844	4	S	"	"	6508	"	"	"	11	"	67.7	.391	6.24	4.80	4.72	66.34	7.2	.061	.0421	1.45	15.6	"	6.40	1.00	9.37
A-176	2	N	W	"	6514	"	"	262.5	12	"	70.1	.404	6.45	4.75	4.74	66.89	9.6	.060	.0425	1.41	14.9	"	6.61	.98	9.56
A1059	4	N	"	K5B I	6508	"	297.5	213.0	11	"	68.8	.396	6.32	4.78	4.87	68.72	8.3	.050	.0449	1.12	12.6	"	6.48	.82	9.27
A-435	3	S	E	"	6514	"	"	208.5	12	"	67.7	.372	5.94	4.90	5.05	71.15	7.2	.032	.0482	.66	8.6	"	6.09	.52	8.58
B-176	3	N	"	"	6514	"	"	"	"	"	67.7	.372	5.94	4.90	5.05	71.16	7.2	.031	.0482	.64	8.3	"	6.09	.51	8.57
B-157	3	N	W	K5B II	6515	"	302.0	265.5	–	"	70.4	.412	6.59	4.69	5.05	71.18	9.9	.030	.0482	.62	7.3	"	6.75	.49	9.21
B-148	3	N	E	K5B I	6509	"	297.5	198.0	–	"	67.7	.423	6.75	4.66	5.11	72.01	7.2	.072	.0494	1.46	17.0	"	6.92	1.18	10.07
A-1107	4	N	W	"	6506	"	"	219.5	8	"	68.8	.401	6.42	4.76	5.29	74.56	8.3	.041	.0530	.77	10.2	"	6.58	.67	9.22
B-860	4	S	"	"	6506	"	"	"	"	"	68.8	.389	6.21	4.82	5.33	75.12	8.3	.077	.0539	1.43	19.8	"	6.37	1.26	9.60

Sheet 4 Span 20

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No	Series	Girder	Direc. of Movement	Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency 'n'	R.P.S. "N"	M.P.H.	Dist "H" (Ft.)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	D L	L L	Imp	Total
A-1076	4	N	W	K5B I	6506	1560	297.5	213.0	6	P	68.8	.384	6.13	4.84	5.33	75.19	8.3	.051	.0538	.95	13.3	1.97	6.28	.84	9.09
B-829	4	S	"	"	6506	"	"	"	"	"	68.8	.411	6.56	4.71	5.33	75.21	8.3	.081	.0538	1.50	19.7	"	6.72	1.32	10.01
B-181	3	S	"	"	6514	"	"	265.0	–	"	70.1	.439	7.00	4.60	5.41	76.21	9.6	.044	.0553	.80	10.0	"	7.18	.72	9.87
A-442	3	N	"	"	6514	"	"	"	–	"	70.1	.406	6.48	4.74	5.42	76.34	9.6	.040	.0556	.72	9.9	"	6.64	.66	9.27
B-845	4	S	"	"	6505	"	"	219.0	9	"	68.8	.383	6.11	4.84	5.48	77.29	8.3	.096	.0568	1.69	25.1	"	6.26	1.57	9.80
A-1092	4	N	"	"	6505	"	"	"	"	"	68.8	.390	6.22	4.81	5.48	77.31	8.3	.041	.0568	.72	10.5	"	6.38	.67	9.02
B-817	4	S	"	K5B III	6531	"	302.0	147.5	8	"	66.1	.407	6.50	4.73	5.68	80.02	5.6	.097	.0610	1.59	23.8	"	6.66	1.59	10.22
A-1064	4	N	"	"	6531	"	"	"	"	"	66.1	.400	6.39	4.77	5.68	80.05	5.6	.049	.0610	.80	12.2	"	6.55	.80	9.32
A-34	1	N	"	K5B I	6513	"	297.5	262.5	–	"	70.1	.367	5.86	4.93	5.73	86.45	9.6	.027	.0621	.43	7.4	"	6.00	.44	8.41
	Average			K5B I	13-Tests	N.	Girder	Westward			69.7	.396	6.32	4.79			9.2					1.97	6.48		
		"		"	7 "	S	"	"			69.5	.410	6.55	4.72			9.0					"	6.71		
		"		"	9 "	N	"	Eastward			68.1	.391	6.24	4.80			7.6					"	6.40		
		"		"	6 "	S	"	"			68.3	.389	6.21	4.82			7.8					"	6.37		
		"		K5B II	1 "	N	"	Westward			70.4	.412	6.59	4.72			9.9					"	6.75		
		"		K5B III	1 "	N	"	"			66.1	.400	6.39	4.78			5.6					"	6.55		
		"		"	1 "	S	"	"			66.1	.407	6.50	4.75			5.6					"	6.66		
		"		"	1 "	N	"	Eastward			70.8	.406	6.48	4.79			10.3					"	6.64		
		"		"	1 "	S	"	"			70.8	.406	6.48	4.79			10.3					"	6.64		
B-149	3	N	W	K3Q	6487	1650	295.5	154.0	–	P	71.9	.410	6.53	4.70	5.49	77.38	13.0	.044	.0603	.73	10.7	1.97	6.69	.72	9.38
A-165	2	N	W	"	6487	"	"	200.0	7	"	71.9	.385	6.13	4.80	5.73	80.84	13.0	.051	.0658	.77	13.2	"	6.28	.83	9.08
			Average 2 Tests N Girder Westward								71.9	.398	6.33	4.75			13.0					1.97	6.49		

Sheet 5 Span 20

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips)		No	Kind	at Dist P	Defl (ins) D	E U L L (Kips)	Loaded Frequency n	R P S N	M P H	Dist H (Ft)	Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier k	Impact γ				
							Eng	Tender														D L	L L	Imp	Total
A-148	2	N	W	K3P II	6483	2075	2891	2025	3	P	700	386	616	476	505	7148	111	.039	0641	61	98	197	631	.62	890
A-179	2	N	W	"	"	"	"	2000	7	-	700	378	603	480	537	75.75	11.1	027	0726	37	71	-	618	.44	859
				Average 2 Tests N Girder Westward							700	382	610	478			11.1					1.97	625		
A-434	3	B	W	K3L	6470	1605	2740	1940	-	P	717	406	648	488	455	6408	13.4	.057	.0403	141	140	197	664	93	954
A-415	3	N	E	K3K	6464	-	-	1800	-	-	717	406	648	488	473	6690	128	047	.0435	108	116	-	664	.77	938
B-158	3	N	-	-	6464	-	-	178.0	-	-	717	.397	633	492	514	7242	128	.032	.0515	62	81	-	649	55	899
A-417	3	B	-	-	6464	-	-	"	-	-	717	.392	625	495	518	7308	128	.030	.0521	58	76	"	641	.49	887
A-422	3	S	W	K3L	6472	-	-	145.0	-	-	65.8	.421	671	481	5.20	7336	75	.095	0526	180	226	-	688	155	1040
B-163	3	N	-	-	6472	-	-	-	-	-	65.8	.379	605	502	525	7402	75	.024	.0537	45	7.9	-	620	49	866
A-431	3	S	E	K3K	6464	-	-	178.0	-	-	71.1	394	628	494	5.33	7521	12.8	.035	.0553	.63	76	-	644	.49	890
B-172	3	N	-	-	6464	-	-	-	-	-	711	.385	613	498	5.33	7521	128	.040	0553	.72	104	-	628	.65	890
A-444	3	N	-	-	6464	-	-	-	-	-	711	.432	689	476	538	7585	128	.070	.0562	124	162	-	706	114	10.17
B-183	3	S	-	-	6464	-	-	-	-	-	711	.372	593	505	538	7585	12.8	.029	.0562	.52	78	-	608	.47	852
			Average 1 Tests N. Girder Westward								658	.379	605	502			7.5					197	620		
				- 2	- S.	-		-			682	.413	659	485			9.9					-	675		
			Average 4 Tests N Girder Eastward								711	.405	646	489			128					-	662		
				" 3	- S.	-		-			71.1	.386	615	4.97			128					-	630		
B-154	3	N	E	KN	6446	1200	2460	125.5	-	P	705	.325	519	519	321	4298	126	.017	.0150	113	5.2	197	532	.28	757
A-153	2	N	-	KO	6451	-	-	129.0	4	-	70.5	.325	5.19	519	3.24	4353	126	.012	.0153	78	3.7	-	5.32	20	749
A-436	3	S	W	KN	6446	-	-	155.0	-	-	722	.369	589	505	459	6145	143	.041	.0307	133	11.1	-	604	.67	868
A-170	2	N	E	KO	6451	-	-	1275	5	-	70.5	.353	563	503	528	7074	126	.026	.0406	.64	7.4	"	5.77	.43	817
			Average 3 Test N. Girder Eastward								705	.334	532	5.14			126					197	545		
				" 1	- S.	-	Westward				722	.369	589	5.05			143					197	604		

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Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips)		No	Kind	at Dist P	Defl (ins) D	E U L L (Kips)	Loaded Frequency n	R P S N	M P H	Dist H (Ft)	Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier k	Impact γ				
							Eng	Tender														D L	L L	Imp	Total
A-426	3	S	E	KB	6412	1250	2228	1185	-	P	711	.350	559	524	291	3889	132	020	0195	103	57	197	573	.33	803
B-178	3	S	-	"	6416	-	"	1230	-	-	711	350	559	524	294	3935	132	017	0200	85	48	-	573	28	798
A-441	3	N	W	-	6412	-	-	1350	-	-	722	.362	578	512	314	41.98	143	017	0228	75	47	-	592	28	817
B-180	3	S	-	-	6412	-	-	-	-	-	722	336	536	527	314	4200	143	017	0228	.75	51	-	550	28	775
A-162	2	N	E	K	6401	-	-	1255	3	-	711	.344	549	527	443	5922	132	.045	0454	99	131	-	563	.74	834
A-448	3	N	W	KB	6416	-	-	1385	-	-	722	357	570	515	445	5948	143	026	0458	57	73	-	584	.43	824
B-187	3	S	-	-	6416	"	-	-	-	-	722	.336	536	527	447	5985	143	.044	.0462	95	122		549	67	813
A-178	2	N	E	K	6401	-	-	1230	8	-	711	.341	544	528	449	6013	132	.051	.0466	109	150	-	558	84	839
A-144	2	N	-	-	6401	"	-	-	-	-	711	348	555	525	452	6052	132	040	.0473	85	115	-	569	65	831
A-428	3	S	W	KB	6412	-	-	1400	-	-	722	.362	578	512	484	6483	143	027	0541	50	75		592	44	833
B-169	3	N	-	-	6412	"	-	-	-	-	722	324	517	534	486	6503	143	.019	0546	35	59		530	31	758
B-156	3	N		-	6416	-	-	1425	-	-	722	352	562	518	485	6489	143	019	0543	35	54		576	31	804
			Average 4 Tests N Girder Westward								722	349	557	520			143					197	571		
				- 3	- S.	-	"				722	345	550	521			143						564		
				- 3	- N	-	Eastward				711	344	549	527			143						563		
				- 2	- S.	-	-				711	350	559	524			143						573		
B-835	4	S	E	L2D	6226	2155	3670	2420	55	F	716	460	734	450	368	4528	91	073	0350	208	159	197	752	120	1069
A-1082	4	N	-	-	6226	"	-	-			716	452	689	461	370	4551	91	082	0354	232	190		706	134	1037
A-161	[illegible]	N	W	-	6228	-	-	2605	65	-	724	454	724	448	416	5115	99	058	0447	130	128	-	742	95	1034
A-424	3	S	E	-	6225	-		2460	37	-	716	469	748	448	459	5655	91	071	0544	131	151	-	767	116	080
B-165	3	N	-	-	6225			-	"	-	716	443	708	457	461	5671	91	059	0550	1.07	133	-	726	97	1020
A-445	3	N	W	-	6228		-	2795	-	-	724	455	726	448	463	5702	99	059	0553	106	130		744	97	1038
B-184	3	S	-	-	6228	-	-	"	-	-	724	429	685	458	463	5702	99	067	0553	121	156	-	702	.10	1009
A-35	1	N		-	6228		-	2675	-	-	724	415	659	465	492	6059	99	062	0627	99	150	-	[illegible]	10	973

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Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"	E U.L L. (Kips)	Loaded Frequency "n"	R.P.S "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat. Defl H Blow D_xN^2 at Center	Dynamic Magnifier "k"	Impact %	D L	L L	Imp.	Total
A-432	3	S	W	L2D	6227	2155	3670	279.5	-	F	72.4	.459	7.32	4.47	5.15	5790	9.9	.073	.0686	1.06	15.9	1.97	7.50	1.19	10.66
B-173	3	N	"	"	6227	"	"	"	–	"	72.4	.451	720	4.49	5.15	5790	9.9	.046	.0686	.67	10.2	"	7.38	.75	10.10
			Average 4 Tests			N Girder Westward					72.4	.443	7.08	4.52			9.9					1.97	7.26		
				" 2	"	S. "		"			72.4	.444	7.09	4.52			9.9					"	7.27		
				" 2	"	N "		Eastward			71.6	.438	6.83	4.60			9.1					"	7.00		
				" 2	"	S "		"			71.6	.464	7.40	4.49			9.1					"	7.59		
B-818	4	S	E	L2C	2859	1854	365.0	238.0	74	F	72.2	.440	7.02	4.57	3.03	37.30	10.3	.041	.0205	2.00	9.3	1.97	7.20	.67	9.84
A-1065	4	N	"	"	2859	"	"	"	"	"	72.2	.417	6.65	4.67	3.05	37.52	10.3	.040	.0208	1.92	9.6	"	6.82	.65	9.44
A-1066	4	N	"	"	2857	"	"	240.0	48	"	72.2	.445	7.10	4.55	3.43	42.26	10.3	.047	.0263	1.79	10.6	"	7.28	.77	10.02
B-819	4	S	"	"	2857	"	"	-	"	"	72.2	.474	7.40	4.44	3.43	42.26	10.3	.053	.0263	2.02	11.2	"	7.59	.85	10.41
B-831	4	S	"	"	2854	"	"	231.0	71	"	72.2	.458	7.30	4.50	3.53	43.46	10.3	.047	.0279	1.68	10.3	"	7.48	.77	10.22
A-1078	4	N	"	"	2854	"	"	"	"	"	72.2	.435	6.94	4.59	3.53	43.49	10.3	.042	.0279	1.50	9.7	"	7.11	.69	9.77
A-1096	4	N	"	"	2891	"	"	255.5	47	"	71.6	.438	7.00	4.58	3.78	46.49	9.7	.046	.0319	1.44	10.5	"	7.18	.75	9.90
B-849	4	S	"	"	2891	"	"	"	"	"	71.6	.463	7.39	4.48	3.79	46.59	9.7	.057	.0321	1.78	12.3	"	7.57	.93	10.47
A-1106	4	N	W	"	2854	"	"	208.0	39	"	70.8	.433	6.90	4.48	4.51	55.45	8.9	.060	.0455	1.32	13.8	"	7.07	.98	10.02
B-859	4	S	"	"	2854	"	"	"	-	"	70.8	.394	6.29	4.65	4.51	55.55	8.9	.090	.0455	1.98	22.8	"	6.45	1.47	9.89
B-830	4	S	"	"	2859	"	"	270.0	49	"	72.6	.421	6.72	4.53	4.60	56.65	10.7	.090	.0473	1.90	21.4	"	6.89	1.47	10.33
A-1077	4	N	"	"	2859	"	"	-	"	"	72.6	.430	6.86	4.50	4.61	56.72	10.7	.069	.0475	1.45	16.0	"	7.03	1.12	10.12
B-843	4	S	"	"	2854	"	"	264.0	37	"	72.6	.427	6.81	4.51	4.62	56.84	10.7	.091	.0477	1.91	21.4	"	6.98	1.49	10.44
A-1090	4	N	"	"	2854	"	"	"	-	"	72.6	.441	7.03	4.45	4.68	57.57	10.7	.057	.0490	1.16	12.9	"	7.21	.93	10.11
A-1104	4	N	"	"	2880	"	"	273.5	62	"	72.6	.437	6.97	4.47	4.67	57.47	10.7	.076	.0487	1.56	17.4	"	7.14	1.24	10.35
B-857	4	S	"	"	2880	"	"	"	"	"	72.6	.427	6.81	4.51	4.68	57.60	10.7	.073	.0490	1.49	17.1	"	6.98	1.19	10.14

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Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D	E U.L L. (Kips)	Loaded Frequency "n"	R.P.S "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat. Defl H Blow D_xN^2 at Center	Dynamic Magnifier "k"	Impact %	D L	L L	Imp	Total
B-826	4	S	W	L2C	2879	1854	365.0	275.0	53	F	72.6	.419	6.68	4.55	4.73	58.20	10.7	.075	.0500	1.50	17.9	1.97	6.85	1.23	10.05
A-1073	4	N	"	"	2879	"	"	"	"	"	72.6	.406	6.48	4.60	4.74	58.29	10.7	.040	.0503	.80	9.9	"	6.64	.66	9.27
A-1089	4	N	"	"	2854	"	"	270.0	56	"	72.6	.421	6.72	4.53	4.98	61.23	10.7	.051	.0556	.92	12.1	"	6.89	.83	9.69
B-842	4	S	"	"	2854	"	"	"	"	"	72.6	.417	6.65	4.55	5.00	61.56	10.7	.069	.0559	1.23	16.5	"	6.82	1.13	9.92
			Average 6 Tests N.			Girder Westward					72.0	.428	6.83	4.50								1.97	7.00		
				" 6	" S	-		-			72.0	.417	6.65	4.55								"	6.82		
				" 4	" N.	"	East	ward			72.0	.434	6.92	4.60								"	7.09		
				" 4	" S.	"		"			72.0	.459	7.33	4.50								"	7.51		
B-152	3	N	E	L2B	6212	1845	364.0	214.0	48	F	71.2	.420	6.70	4.56	3.05	37.54	8.7	.026	.0206	1.26	6.2	1.97	6.87	.43	9.27
A-1093	4	N	"	"	6213	"	"	221.0	73	"	71.2	.394	6.29	4.68	3.62	44.48	8.7	.052	.0290	1.79	13.2	"	6.45	.85	9.27
B 846	4	S	"	"	6213	"	"	"	"	"	71.2	.403	6.43	4.64	3.64	44.89	8.7	.046	.0293	1.57	11.4	"	6.59	.75	9.31
A-425	3	S	"	"	6213	"	"	222.0	56	"	71.2	.450	7.17	4.43	3.62	44.59	8.7	.036	.0290	1.24	8.0	"	7.35	.59	9.91
B-166	3	N	"	"	6213	"	"	"	"	"	71.2	.406	6.47	4.63	3.64	44.73	8.7	.036	.0293	1.23	8.8	"	6.63	.58	9.18
B-150	3	N	"	"	6215	"	"	221.5	–	"	71.2	.474	7.40	4.35	3.72	45.81	8.7	.059	.0306	1.60	10.3	"	7.59	.78	10.34
A-419	3	S	W	"	6214	"	"	254.0	–	"	72.1	.438	6.99	4.50	3.98	49.00	9.6	.040	.0350	1.14	9.1	"	7.16	.65	9.78
B-160	3	N	"	"	6214	"	"	"	–	"	72.1	.421	6.71	4.57	3.99	49.08	9.6	.024	.0352	.68	5.7	"	6.88	.39	9.24
A-171	2	N	E	"	6214	"	"	234.5	57	"	71.2	.390	6.21	4.70	3.99	49.04	8.7	.033	.0352	.94	7.0	"	6.37	.45	8.79
A-154	2	N	"	"	6214	"	"	208.5	52	"	71.2	.430	6.86	4.52	4.28	52.69	8.7	.093	.0406	2.29	21.6	"	7.03	1.52	10.52
A-152	2	N	"	"	6209	"	"	216.0	48	"	71.2	.434	6.92	4.50	4.28	52.64	8.7	.112	.0406	2.76	25.8	"	7.09	1.83	10.89
			Average 1 Tests			N. Girder Westward					72.1	.421	6.71	4.57			9.6					1.97	6.88		
				" 1	"	S "		"			72.1	.438	6.99	4.50			9.6					"	7.16		
				" 7	"	N. "		Eastward			71.2	.421	6.71	4.55			8.7					"	6.88		
				" 2	"	S. "		"			71.2	.427	6.81	4.54			8.7					"	6.98		

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Test		Girder	Direc of Movement	Locomotive					Cars		Stat. L.L. Defl.		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat Defl H Blow $D_x N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H.	Meas Oscill (ins)	Corr Oscill (ins)				DL	LL	Imp	Total
A-175	2	N	E	H10A I	13	1270	335.0	225.0	75	F	68.3	.424	6.76	4.53	3.27	36.72	10.4	.017	.0164	1.03	4.0	1.97	6.93	.28	9.18
A-158	2	N	E	-	48	..	-	230.6	75	..	68.3	.420	6.70	4.55	3.34	37.48	10.4	.020	.0171	1.17	4.8	-	6.87	.33	9.17
A-1080	4	N	W	H10A II	148	1390	-	270.0	62	-	69.3	.424	6.76	4.54	4.01	45.08	11.3	.086	.0270	3.18	20.3	-	6.93	1.41	10.31
B-833	4	S	-	-	148	-	-	-	-	-	69.3	.435	6.94	4.50	4.05	45.53	11.3	.086	.0276	3.12	19.8	-	7.11	1.41	10.49
B-834	4	S	E	-	97	-	-	227.5	13	-	66.9	.448	7.14	4.49	4.11	46.20	8.9	.053	.0284	1.87	11.8	-	7.32	.86	10.15
A-1081	4	N	-	-	97	..	-	-	-	-	66.3	.441	7.04	4.51	4.12	46.33	8.9	.036	.0285	1.26	8.2	-	7.22	.59	9.78
B-854	4	S	-	H10A-I	48	1270	-	230.0	32	-	68.3	.431	6.88	4.50	4.15	46.71	10.4	.050	.0263	1.91	11.6	-	7.05	.82	9.84
A-1101	4	N	-	-	48	-	-		-	..	68.3	.422	6.73	4.54	4.16	46.76	10.4	.050	.0265	1.89	11.8	-	6.90	.81	9.68
A-1071	4	N	W	H10A-II	97	1390	-	267.5	18	-	69.3	.427	6.81	4.53	4.16	46.77	11.3	.030	.0291	1.03	7.0	-	6.98	.49	9.44
B-824	4	S	-	-	97	-	-	-	-	..	69.3	.456	7.27	4.42	4.16	46.77	11.3	.026	.0291	.89	5.7	-	7.45	.42	9.84
B-839	4	S	-	H10A-I	42	1270	-	265.0	23	-	79.9	.436	6.95	4.64	4.47	50.23	22.0	.043	.0305	1.41	9.8	-	7.12	.70	9.79
A-1086	4	N	-	-	42	..	-	-	-	-	79.9	.417	6.66	4.72	4.49	50.48	22.0	.036	.0308	1.17	8.6	-	6.83	.59	9.39
B-853	4	S	E	H10A-II	158	1390	..	225.5	1	-	66.9	.451	7.20	4.47	4.54	51.01	8.9	.053	.0347	1.53	11.8	-	7.38	.87	10.22
A-1100	4	N	-	-	158	-	-	..	-	-	66.9	.419	6.69	4.61	4.56	51.25	8.9	.047	.0350	1.34	11.2	-	6.86	.77	9.60
		Average		H10A I	1 Tests	N Girder	Westward				79.9	.417	6.66	4.72			22.00					1.97	6.83		
		-		-	1 -	S. -		-			79.9	.436	6.95	4.64			22.00					-	7.12		
		-		-	3 -	N. -	Eastward				68.3	.422	6.73	4.54			10.4					-	6.90		
		-		-	1 -	S. -		-			68.3	.431	6.88	4.50			10.4					-	7.05		
		-		H10A II	2 -	N -	Westward				69.3	.426	6.79	4.54			11.3					-	6.96		
		-		-	2 -	S -		-			69.3	.446	7.12	4.45			11.3					-	7.30		
		..		-	2 ..	N ..	Eastward				66.9	.430	6.86	4.56			8.9					-	7.03		
		..		-	2 ..	S -		..			66.9	.449	7.16	4.48			8.9					-	7.34		

Sheet 10 Span 20

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat Defl H Blow $D_x N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R P S "N"	M P H	Dist "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
B-153	3	N	E	H7E III	6179	2455	335.9	130.0	-	F	67.9	.453	7.23	4.61	3.40	38.25	10.0	.030	.0342	.88	6.6	1.97	7.41	.49	9.87
A-155	2	N	-	H7E V	6159	-	343.1	185.0	48	-	67.3	.442	7.06	4.58	3.63	40.85	9.4	.059	.0390	1.51	13.3	..	7.24	.96	10.17
A-427	3	S	-	-	6153	-	-	193.0	29	-	67.3	.461	7.36	4.50	3.75	42.15	9.4	.071	.0416	1.71	15.4	-	7.54	1.16	10.67
A-146	2	N	W	..	6159	-	..	266.0	—	-	68.9	.444	7.08	4.57	3.84	43.18	9.0	.083	.0436	1.90	18.7	-	7.26	1.36	10.59
A-430	3	S	-	H7E III	6179	-	335.9	175.6	—	-	69.9	.456	7.28	4.58	3.87	43.55	8.0	.030	.0443	.68	6.6	-	7.46	.49	9.92
A-440	3	N	-	H7E V	6153	-	343.1	270.0	—	-	68.9	.479	7.65	4.44	4.13	46.47	9.0	.077	.0505	1.53	16.1	-	7.84	1.26	11.07
B-179	3	S	-	..	6153	-	-	..	—	-	68.9	.481	7.67	4.43	4.19	47.06	9.0	.099	.0520	1.90	20.6	-	7.86	1.62	11.45
B-155	3	N	-	-	6153	-	-	258.0	—	-	68.9	.456	7.28	4.52	4.19	47.09	9.0	.027	.0520	.52	5.9	-	7.46	.44	9.87
A-160	2	N	-	H7E II	6168	-	334.9	171.0	—	..	70.0	.423	6.75	4.59	4.23	47.56	8.1	.076	.0530	1.43	18.0	-	6.92	1.25	10.14
	Average			H7E-II	1 Test	N Girder	Westward				70.0	.423	6.75	4.59			8.1					1.97	6.92		
		..		H7E III	1 -	S -		-			69.9	.456	7.28	4.58			8.0					-	7.46		
		-		- -	1 -	N -	Eastward				67.9	.453	7.23	4.61			10.0					-	7.41		
		-		H7E V	3 -	N -	Westward				68.9	.460	7.34	4.51			9.0					-	7.52		
		..		-	1 ..	S		-			68.9	.481	7.67	4.43			9.0						7.86		
		-		-	1 -	N -	Eastward				67.3	.442	7.06	4.58			9.4					-	7.24		
		-		..	1 ..	S -		..			67.3	.461	7.36	4.60			9.4					-	7.54		
A-1061	4	N	W	H6A	6106	2136	290.8	178.0	37	F	71.3	.381	6.08	4.75	2.20	24.81	15.4	.020	.0123	1.62	5.2	1.97	6.23	.32	8.52
B-814	4	S	-	-	6106	..	-	-	-	-	71.3	.365	5.83	4.84	2.21	24.96	15.4	.020	.0124	1.61	5.5		5.98	.33	8.28
A-1095	4	N	E	..	6101	-	-	147.0	36		69.8	.381	6.08	4.83	4.09	46.02	13.9	.073	.0425	1.71	19.2	-	6.23	1.20	9.40
B-848		S		..	6101		-		-		69.8	.394	6.29	4.77	4.09	46.00	13.9	.076	.0425	1.79	19.3	-	6.45	1.24	9.66
																						1.97			

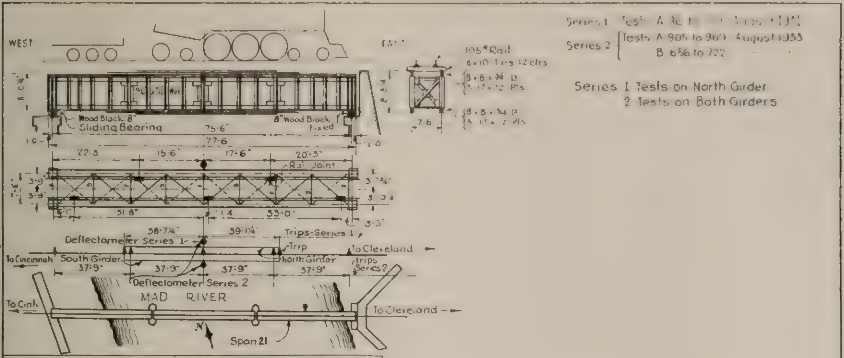
Sheet 11 Span 20.

Test No	Series	Girder	Direc of Movement	Locomotive Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist "P"	Stat L L Defl Defl (ins) D	E U L L (Kips)	Loaded Frequency 'n'	Speed R P S "N"	Speed M P H	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow $D_x N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
A 1087	4	N	E	H50 II	6704	2090	275.7	134.0	21	F	706	.372	5.94	492	2 05	2303	131	.015	.0106	141	40	197	609	.24	8 30
B-840	4	S	·	··	6704	·	·	·	··	··	706	349	5 57	5.04	2 08	2341	131	.017	.0109	156	49	·	571	28	7.96
A 164	2	N	W	-	6059	··	··	1170	1	··	71 3	.352	562	5.10	2 07	2321	138	.012	.0108	1.11	3.4	··	576	.20	793
A 166	2	N	E	-	6059	-	-	1220	17	-	706	.324	5 17	5 18	2.08	2336	13.1	.011	.0109	1.01	3.4	-	5 30	18	745
A 163	2	N	·	·	6059	·		129.5	-	-	706	335	5.35	5 11	2.40	2701	131	.013	.0146	89	39	··	5.48	21	7.66
B-174	3	N	·	·	6713		·	1220	-	··	706	335	535	5.10	2.82	3167	131	013	.0201	65	39	-	548	21	765
A-433	3	S		··	6713	·	··	··	-	·	706	.394	629	481	2 82	31 68	13.1	.017	.0201	85	43	·	6.45	.28	870
A-147	2	N	··	·	6709		·	126.5	-	··	70.6	.323	5.16	5.18	299	3360	13.1	.022	.0225	98	6.8	-	529	36	7.62
A 1102	4	N	·	·	6704	·	··	130 0	9	·	70.6	356	568	500	305	3427	131	.036	.0235	1 53	101	-	5.82	59	8.38
B 855	4	S	··	··	6704	··		··	··		706	.359	573	498	305	34 27	13.1	.032	.0235	1.36	89		5.87	.52	836
B-182	3	S			6709	·	·	130.5	-	·	70.6	.364	581	496	362	4069	131	.018	.0330	55	49	·	596	29	822
A-443	3	N			6709	·	··	·	-	·	706	.394	6.29	481	363	4085	131	.027	.0333	.81	69	-	645	.45	8.87
B-832	4	S	W		6704	·	·	147.5	6	·	71.3	376	600	498	3.78	4254	138	066	.0360	1.83	176	··	6.15	1.08	9.20
A-1079	4	N	·	··	6704	·	-		··	·	71 3	.373	5.96	499	3 79	4261	13.8	052	.0363	1.43	139	··	6.11	.85	893
A 1094	4	N	-	··	6704	·	·	148.0	16	·	713	.392	6.26	490	3.86	4338	13.8	.073	.0376	1.94	186	·	642	1.19	9.58
B-847	4	S	·	-	6704	··			·	·	71 3	374	597	499	3.86	4338	138	.078	.0376	2.07	20.8	-	6.12	1.27	9.36
A-423	3	S	·	·	6713	··	··	147.5	23	-	71 3	433	6.92	471	391	4400	13.8	.051	.0386	1.32	11 8	·	709	84	9.90
B-164	3	N		-	6713	·	·	-	··	·	71.3	325	518	525	3.93	4415	138	.020	.0390	.51	5.3	-	531	28	7.56
A-438	3	N	·	··	6709			142.5	··	·	71 3	399	6.37	487	4.17	4683	138	.033	.0440	75	82	·	6.53	.54	9.04
		Average		5 Tests	N	Girder	Westward				71.3	368	588	502			138					197	603		
			··	3 ·	S						71 3	394	629	489			13.8					·	645		
			··	7 ··	N	·	Eastward				706	348	556	504			131					··	5.70		
				4	S	·					706	.367	3.67	494			13.1					··	6.01		

Sheet 12 Span 20

Test No	Series	Girder	Direc of Movement	Locomotive Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist "P"	Stat L L Defl Defl (ins) D	E U L L (Kips)	Loaded Frequency 'n'	Speed R P S "N"	Speed M P H	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow $D_x N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens. Net Sec DL	L.L.	Imp.	Total
A-1062	4	N	E	H5LAI	6142	2092	2778	121 0	12	F	70 6	371	592	4 87	2 39	2690	131	.026	.0144	181	70	1.97	607	42	8 46
B-815	4	S	·	··	6142	··	-	-	·	··	70 6	351	5.60	498	2 40	2694	131	.025	.0145	1.72	7.1	-	5.74	41	8 12
A-177	2	N	·	H5L I	6002	··	275.7	134 0	4	-	70.6	.307	4.90	5.11	2 61	29.34	131	.017	.0171	.99	55	-	5.02	28	7 27
A-1072	4	N	E	H5LA I	6142	··	277.8	130.0	4	··	70.6	.370	5.90	4 87	3.05	34 24	131	.040	0234	1.71	10.8	·	6.05	.65	8 67
B-824	4	S	··	··	6142	·	··	··	·	·	70.6	.369	5.89	4 88	3.05	34 24	131	.043	0234	1.84	11 6	-	6.04	.70	8 71
A-418	3	S	-	H5LI	6002	··	275 7	130.0	12	··	70 6	.382	6 10	4 71	3.31	3721	13.1	.031	0275	1.12	8.1	-	6 25	51	8.73
B-159	3	N	-	·	6002	··	·	··	··	··	70 6	.346	5.52	4 90	3.37	3783	13.1	.031	.0285	1.09	9.0	-	5.66	51	8 14
A-1067	4	N	W	H5LAI	6142	·	2778	125.5	21	··	70.6	.368	5.87	490	3.92	44.04	131	.013	.0387	34	35	-	6.02	.21	8.20
B-820	4	S	W	··	6142	·	··	··	··	·	70 6	.372	594	4 87	3.95	4444	131	.101	.0392	2 58	269	·	6.09	164	970
B-151	3	N	-	H5LI	6002	··	275.7	131 5	2	··	70 6	413	6 59	4 90	4 22	4739	131	043	.0447	.96	10.4	-	6 75	.70	9 42
	Average			H5LI 1	Tests	N Girder	Westward				70.6	.413	6 59	4 90			131					197	6 75		
		-		2	-	N ··	Eastward				70.6	.327	5 22	5.00			13.1					··	5 35		
		·		1	·	S ··		··			70 6	.382	6 10	4.71			131					··	6 25		
		·		1		N ·	Westward				70.6	.368	5 87	4 90			131					·	6 02		
		·		1	·	S ··		··			70 6	.372	5 94	4 87			13.1					··	6 09		
		··		2	·	N ·	Eastward				70.6	.371	5.92	4 87			131					·	6 07		
		-		2	··	S ··		··			70.6	.360	5 75	4 93			13.1					··	5 89		

NOTE.-Frequencies shown are theoretical frequencies without damping
actual frequencies are about 98.5% of the above
D.L Deflection = .1203"
Deflection per 1000* per Ft. = .0627"
Stress per 1000* per Ft = 960*



Series 1 Tests A ... to ... 1931
Series 2 {Tests A 905 to 969 August 1933
B 656 to 722

Series 1 Tests on North Girder
2 Tests on Both Girders

DESIGN DATA		
Date 1913	Spec. 1910	
Material O H Steel		
Loading E-60	E.U.L.L.	8220
Flange Stress	D.L.	1720
(Tens. N. Sec.)	L.L.	8070
	Imp.	6450
	Total	16240
Gross M. of I. at Center		501080
Weight Steel per Ft.		1245
Weight Deck per Ft.		510
Total per Ft.		1755
Total for Span		136000

COMPUTED DEFLECTION (from gross M. of I.)	
For 1000 Lbs. per Ft. Trk.	.0544
For 1000 Lbs. at Center	.00107
D.L. Deflection	.0954
D.L. Frequency	11.07

COMPUTED FROM TESTS (using Aver. M. of I. 449470)	
Deflec. 1000 Lbs. per Ft. Trk.	.0606
Deflec. 1000 Lbs. at Center	.00119
Deflec. D.L.	.1063
Frequency D.L.	10.48
$\frac{\text{Average Observed M. of I.}}{\text{Comp. Gross M. of I.}}$	.897

LOCOMOTIVES USED IN TESTS

Class of Engines	K N	K3K	K5B (III)	J1D		K5B II	K5B I	K3P I	K5Q	
Engines per class	1	5	9	8		5	2	1	3	
Tests per class	1	20	32	28		14	4	4	8	
Class of Engines	H5LA (I)	H5LA (III)	H5T	H10A (III)	H10A II	H10B I	H6A	H7E I		
Engines per class	1	1	1	2	4	4	2	1		
Tests per class	1	1	1	3	15	8	6	2		

SPAN 21

Bridge 122 Cincinnati Div
East Span Single Track
77-6" Deck Plate Girder

Fig. 62

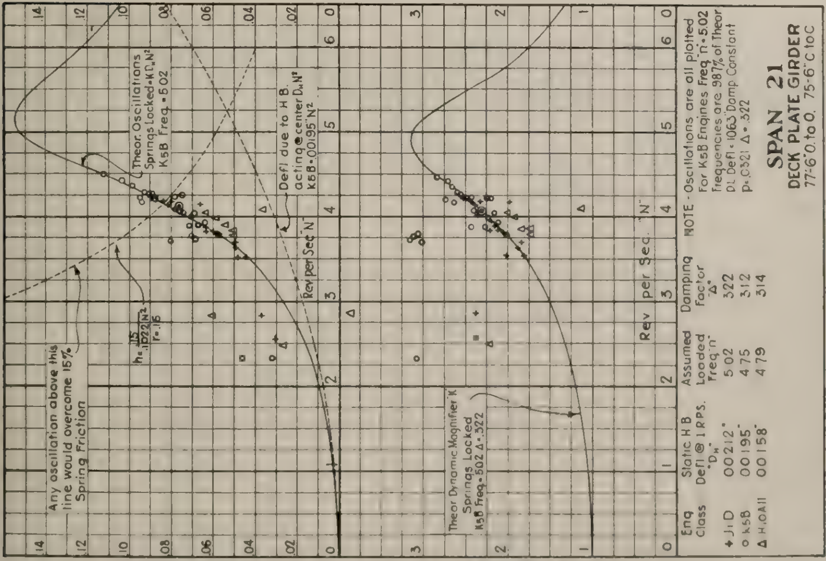


Fig. 63

TABLE XXXV

BRIDGE 122 CINCINNATI DIV 77'-6" D.P. GIRDER

Sheet 1 Span 21

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No	Series			Class	Eng No	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R.P.S. "N"	M.P.H.	Dist "H" (Ft)	Oscil (ins)				D L	L L	Imp.	Total
B-693	2	N	E	J1D	6601	1690	3530	2156	8	P	68.3	404	667	493	2.55	3601	11 4	.030	0138	217	74	1.72	6.53	48	873
A 940	"	S	"	"	"	"	"	"	"	"	"	.424	7.00	484	256	3606	"	036	.0139	259	8.5	"	6.85	58	9.15
B-721	"	N	"	"	6619	"	"	2122	7	"	"	417	689	487	286	4037	"	045	0173	260	108	"	675	.73	920
A 968	"	S	"	"	"	"	"	"	"	"	"	419	691	486	287	4047	"	038	0174	218	9.1	"	678	.68	918
A-99	1	N	"		6614	"	"	195.0	10	"	"	416	686	487	353	4987	"	.053	.0264	201	12.7	"	674	86	9.32
A-927	2	S	"	"	6601	"	"	244.2	8	"	"	.456	753	4.70	352	4985	"	.044	.0262	1.68	97	"	739	.72	9.83
B-680	"	N	"	"		"	"	"	"	"	"	430	710	481	3.53	4990	"	.051	.0264	193	11.9	"	695	.83	9.50
B-664	"	N	"	"	6601	"	"	2156	8	"	"	.430	710	481	363	5130	"	.060	.0279	2.14	140	"	695	.97	9.64
A-912	"	S		"	"	"	"	"	"	"	"	.418	690	486	365	5153	"	.046	.0282	1.63	11.0	"	676	74	9.22
A-102	1	N	W	"	6602	"	"	2438	9	"	"	424	7.00	482	3.70	5230	"	.053	.0290	1.83	12.5	"	6.85	.86	9.43
B-713	2	N	E	"	6601	"	"	233.2	11	"	"	422	696	4.85	382	5400	"	066	.0309	214	156	"	6.83	1.06	9.61
A-960	"	S	"	"	"	"	"	"	"	"	"	.417	6.89	4.87	384	54.15	"	062	.0312	198	149	"	6.75	101	9.48
A-108	1	N	"		6609	"	"	2193	10	"	"	435	7.18	4.79	384	5430	"	.069	0312	2.21	15.9	"	704	1.12	9.88
A-955	2	S	"	"	6619	"	"	2122	8	"	"	.427	705	482	383	5400	"	.056	.0310	1.81	13.1	"	691	.91	9.54
B-708	"	N	"	"	"	"	"	"		"	"	448	740	473	387	5460	"	.076	.0317	2.40	17.0	"	7.25	1.23	1020
B-679	"	N	"	"	6601	"	"	253.0	8	"	"	.432	714	480	390	5505	"	.069	.0322	2.14	16.0	"	7.00	1.12	9.84
A-941	"	S	W	"	6618	"	"	2375	4	"	"	.399	659	494	393	55.53	"	.071	.0327	217	178	"	645	1.15	9.32
B-694	"	N	"	"	"	"	"	"	"	"	"	.384	634	501	394	5560	"	.071	.0329	216	185	"	6.21	1.15	9.08
A-956	"	S	"	"	6619	"	"	2438	9	"	"	.444	733	4.72	405	5715	"	.083	.0347	2.39	18.7	"	7.18	1.34	10.24
B-709	"	N	"	"	"	"	"	"	"	"	"	.430	710	480	405	5715	"	.081	.0347	234	188	"	695	1.31	9.98
A-926	"	S	"	"	6616	"	"	2420	4	"	"	.417	689	484	415	5855	"	.085	.0365	233	20.4	"	675	1.38	985
B-678	"	N	"	"	"	"	"	"	"	"	"	448	740	471	415	5860	"	091	.0365	249	203	"	725	1.47	1044
A-110	1	N	"	"	6619	"	"	2395	5	"	"	425	701	481	417	5886	"	.073	.0368	1.99	172	"	6.88	118	978
B-696	2	N	"	"	6619	"	"	244.2	9	"	"	.439	725	475	418	5893	"	.076	.0370	2.06	173	"	7.10	123	10.05
A-943	"	S	"	"	"	"	"	"	"	"	"	.427	7.05	480	419	59.10	"	.097	0371	261	227	"	6.91	1.57	10.20

Sheet 2 Span 21

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R.P.S. "N"	M.P.H.	Dist "H" (Ft)	Oscil (ins)				D L	L L	Imp	Total
A-100	1	N	E	J1D	8225	1690	3530	1911	5	P	683	419	6.91	486	419	59.15	11.4	.091	0371	245	21.7	1.72	678	147	987
B-666	2	N	W	"	6601	"	"	2442	9	"	"	423	698	482	425	60.00	"	.088	0382	230	20.8	"	6.85	142	9.99
A-914	"	S	"	"	"	"	"	"	"	"	"	.437	722	476	426	60.07	"	106	.0385	276	24.3	"	7.07	172	10.51
			Average	12 Tests	Westward						683	.425	701	481			11.4					1.72	6.87		
				" 16 "	Eastward						68.3	.426	703	4.83			114					172	6.89		
A-109	1	N	W	K5BIII	6534	1560	3020	1455	8	P	631	.424	7.00	497	2.35	3311	62	.047	.0107	440	111	172	6.85	76	933
A-109	"	"	"	"	6536	"	"	"	"	"	"	422	696	498	235	3311	"	.033	.0107	308	7.8	"	6.83	.53	9.08
A-911	2	S	"	K5BII	6516	"	"	2188	6	"	65.0	.405	669	5.06	369	5210	81	.086	0265	3.24	21.2	"	6.55	1.39	966
B-663	"	N	"	"	"	"	"	"	"	"	"	373	6.15	523	3.74	5283	"	.076	.0272	2.80	204	"	604	1.23	899
A-969	"	S	"	"	6515	"	"	218.2	5	"	"	391	6.45	513	3.75	5295	"	068	0273	249	174	"	633	110	9.15
B-722	"	N	"	"	"	"	"	"	"	"	"	.396	654	510	3.76	5303	"	106	0275	3.86	26.8	"	640	171	9.83
A-961	"	S	"	"	6520	"	"	2315	7	"	"	.388	6.40	5.15	3.79	53.50	"	106	.0279	380	273	"	628	171	9.71
B-714	"	N	"	"	"	"	"	"	"	"	"	.441	728	489	379	53.57	"	068	.0279	244	154	"	7.15	1.10	9.97
A-947	"	S	"	"	6519	"	"	231.1	9	"	"	.427	705	496	381	5368		068	.0282	241	159	"	691	1.10	9.73
B-700		N	"	"	"	"	"	"	"	"	"	.388	6.40	515	3.81	53.76	"	106	.0282	376	273	"	628	171	971
B-670	"	N	E	"	6519	"	"	193.3	10	"	"	.417	689	5.03	3.90	55.03	"	.082	.0295	278	19.7	"	675	133	980
A-918	"	S	"	"	"	"		193.3	"	"	"	.382	630	5.22	3.91	5515	"	.063	0297	212	165	"	618	102	892
A-98	1	N	"	K5BIII	6534	"	"	110.8	"	"	631	.399	6.59	509	392	5535	62	.068	.0299	228	170	"	6.46	110	927
A-106	"	"	"	"	6531	"		980	9	"	"	341	563	5.40	3.95	5590	"	.065	.0203	214	191	"	551	105	828

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Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_x N^2$ at Center	Dynamic Magnifier 'k'	Impact γ	Moment Unit Stress (Kips) Tens Net Sec			
No.	Series			Class	Eng No.	H.B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D			R.P.S. 'N'	M.P.H.	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-931	2	S	E	K5B III	6533	1560	302.0	115.9	10	P	63.1	.364	600	527	401	5668	62	.066	.0312	212	181	172	573	104	849
B-684	"	N	"	"	"	"	"	"	"	"	"	.418	6.90	499	4.04	5695	"	.076	.0317	240	18.2	"	676	123	971
B-687	"	N	"	"	6531	"	"	130.9	5	"	"	.385	6.35	5.16	4.02	56.70	"	.086	.0314	2.74	22.5	"	625	1.39	9.34
A-934	"	S	"	"	"	"	"	"	"	"	"	.400	6.60	5.08	407	5745	"	.063	.0321	196	15.7	"	6.47	102	9.21
B-705	"	N	W	"	6539	"	"	157.4	4	"	"	.376	620	5.21	405	5710	"	.066	.0319	207	17.5	"	6.09	1.06	887
A-952	"	S	"	"	"	"	"	"	"	"	"	.392	646	512	406	5720	"	.073	.0320	2.28	18.6	"	635	1.18	9.25
B-665	"	N	"	"	6538	"	"	146.3	4	"	"	.405	669	5.05	406	5730	"	.081	.0320	253	20.0	"	655	131	958
A-913	"	S	"	"	"	"	"	"	"	"	"	.428	706	495	407	5750	"	.071	.0321	2.21	16.6	"	692	115	979
A-946	"	S	E	"	6535	"	"	115.9	10	"	"	.425	701	495	410	5790	"	.078	.0326	2.39	18.3	"	688	126	986
B-699	"	N	"	"	"	"	"	"	"	"	"	.424	7.00	496	410	5790	"	.078	.0326	2.39	18.4	"	685	126	983
A-939	"	S	W	"	6540	"	"	157.8	4	"	"	.396	654	5.10	410	5790	"	.076	.0326	233	19.2	"	6.40	123	935
B-692	"	N	"	"	"	"	"	"	"	"	"	.388	6.40	5.15	410	5795	"	.081	.0326	2.48	20.4	"	6.28	128	928
B-672	"	N	E	"	6540	"	"	130.7	5	"	"	.413	6.81	5.02	408	57.55	"	.087	.0324	2.68	21.1	"	6.68	141	981
A-920	"	S	"	"	"	"	"	"	"	"	"	.369	610	524	412	5810	"	.071	.0330	216	19.2	"	597	115	884
B-685	"	N	W	K5B I	6509	"	297.5	231.5	7	"	65.0	.412	680	505	419	59.10	8.1	.099	.0341	2.90	240	"	6.66	160	9.98
A-932	"	S	"	"	"	"	"	"	"	"	"	.416	6.86	5.02	4.19	59.10	"	.082	.0341	240	197	"	674	1.33	9.79
B-716	"	N	E	K5B III	6540	"	302.0	130.7	6	"	63.1	.416	6.86	5.00	420	59.20	62	.091	.0343	266	218	"	674	1.47	993
A-962	"	S	"	"	"	"	"	"	"	"	"	.371	6.12	5.23	4.27	6040	"	.101	.0355	2.85	272	"	6.00	1.63	9.35
A-906	"	S	"	"	6537	"	"	127.8	5	"	"	.364	6.00	5.28	423	5970	"	.109	.0348	3.14	30.0	"	5.89	1.77	9.38
B-657	"	N	"	"	"	"	"	"	"	"	"	.407	672	505	426	60.05	"	.066	.0353	187	162	"	6.59	1.07	938
A-905	"	S	W	K5B II	6518	"	"	2236	7	"	65.0	.423	6.98	4.98	425	601	81	.088	.0351	250	20.8	"	6.84	1.42	9.98
B-656	"	N	"	"	"	"	"	"	"	"	"	.402	664	508	4.25	6013	"	.071	.0351	202	177	"	6.50	1.15	9.37
A-954	"	S	"	"	6515	"	"	219.8	4	"	"	.423	6.98	498	426	6014	"	.087	.0353	246	206	"	6.84	1.41	9.97
B-707	"	N	"	"	"	"	"	"	"	"	"	.371	612	5.23	426	60.15	"	.071	0353	201	19.2	"	6.00	1.15	8.87

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Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_x N^2$ at Center	Dynamic Magnifier 'k'	Impact γ	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D			R.P.S. 'N'	M.P.H.	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-948	2	S	E	K5B III	6537	1560	302.0	130.7	5	P	63.1	.403	665	506	426	6015	62	.085	.0353	240	211	1.72	6.51	138	961
B-701	"	N	"	"	"	"	"	"	"	"	"	.397	6.55	509	426	6015	"	.106	.0353	3.01	267	"	642	172	9.86
A-910	"	S	W	"	6533	"	"	1574	4	"	"	.398	6.57	510	428	6040	"	.081	0356	228	203	"	6.44	131	947
B-662	"	N	"	"	"	"	"	"	"	"	"	.356	5.87	532	4.28	6045	"	.101	.0356	2.84	28.4	"	5.76	1.64	9.12
B-677	"	N	"	"	6537	"	"	1574	4	"	"	.386	6.37	515	429	6050	"	.083	.0358	232	21.5	"	625	134	9.31
A-925	"	S	"	"	"	"	"	"	"	"	"	402	6.64	508	430	6076	"	.103	.0360	286	256	"	650	166	9.88
A-919	"	S	"	K5B I	6514	"	297.5	229.9	7	"	65.0	.421	695	5.00	437	6170	8.1	113	.0370	305	268	"	6.81	183	1036
B-671	"	N	"	"	"	"	"	"	"	"	"	366	6.05	5.27	438	6190	"	.085	0372	228	232	"	592	151	915
B-669	"	N	"	K5B III	6539	"	302.0	153.5	4	"	63.1	.398	6.57	510	444	6260	62	109	.0383	285	27.4	"	644	176	992
A-917	"	S	"	"	"	"	"	"	"	"	"	.418	690	500	445	6275	"	101	.0385	263	242	"	6.76	164	1012
B-697	"	N	"	"	6534	"	"	153.5	5	"	"	.394	650	512	450	6355	"	.096	.0393	244	244	"	637	155	964
A-944	"	S	"	"	"	"	"	"	"	"	"	.422	6.96	498	451	6375	"	.113	.0395	2.86	268	"	683	183	1038
Average K5B I 4 Tests Westward											65.0	.404	667	508			81					172	653		
	"			K5B II	12 Tests Westward						65.0	.402	6.64	5.08			8.1					172	651		
	"			"	2 " Eastward						65.0	.400	660	5.12			8.1					172	647		
	"			K5B III	16 " Westward						63.1	400	660	509			62					172	648		
	"			"	16 " Eastward						631	.393	649	512			62					172	636		
A 930	2	S	W	K3Q	6498	1650	2955	1617	4	P	620	.417	689	497	386	5455	57	.071	.0307	2.31	17.0	1.72	675	115	9.62
B-683	"	N	"	"	"	"	"	"	"	"	"	380	627	510	387	5460	"	056	0309	1.81	14.7	"	615	90	877
B-717	"	N	E	"	6491	"	"	1189	8	"	63.0	.378	6.24	512	410	5790	67	093	0346	269	246	"	611	1.50	933
A-964	"	S	"	"	"	"	"	"	"	"	"	376	620	513	4.10	5795	"	.071	0346	205	18.9	"	609	1.15	896
B-699	"	N	E	"	6490	"	"	139.0	10	"	630	.390	644	506	410	5800	67	105	0346	304	269	"	631	1.70	973
A-946	"	S	"	"	"	"	"		"	"	"	.384	634	509	4.10	5800	"	071	0346	205	185	"	621	115	908

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Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series	Girder	Direc. of Movement	Class	Eng No.	H.B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No.	Kind	at Dist "P"	Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L.	L.L.	Imp	Total
A-935	2	S	W	K3Q	6490	1650	295.5	157.6	5	P	62.0	.389	6.42	5.05	4.21	59.50	5.7	.105	.0365	2.88	27.0	1.72	6.30	1.70	9.72
B-688	"	N	"	"	"	"	"	"	"	"	"	.352	5.80	5.25	4.21	59.50	"	.083	.0365	2.27	23.6	"	5.70	1.35	8.77
				Average	4 Tests Westward						62.0	.385	6.35	5.07			5.7					1.72	6.23		
				"	4 " Eastward						63.0	.382	6.31	5.10			6.7					1.72	6.18		
A-950	2	S	E	K3PI	6476	2076	280.2	108.9	5	P	61.9	.377	6.22	5.20	2.72	38.32	5.6	.050	.0192	2.60	13.3	1.72	6.10	.81	8.63
B-703	"	N	"	"	"	"	"	"	"	"	"	.362	5.97	5.29	2.73	38.46	"	.055	.0194	2.84	15.2	"	5.85	.88	8.45
B-712	"	N	W	"	"	"	"	167.1	4	"	64.0	.404	6.67	5.12	3.87	54.57	7.7	.052	.0390	1.33	12.9	"	6.53	.84	9.09
A-959	"	S	"	"	"	"	"	"	"	"	"	.385	6.35	5.22	3.88	54.83	"	.071	.0391	1.82	18.4	"	6.23	1.15	9.10
				Average	2 Tests Westward						64.0	.395	6.51	5.17			7.7					1.72	5.98		
				"	2 " Eastward						61.9	.370	6.10	5.24			5.6					1.72	6.38		
B-695	2	N	W	K3K	6467	1603	274.0	199.5	3	P	63.9	.382	6.30	5.13	2.19	30.90	7.6	.040	.0097	4.13	10.5	1.72	6.18	.65	9.05
A-942	"	S	"	"	"	"	"	"	"	"	"	.356	5.88	5.27	2.21	31.15	"	.035	.0098	3.57	9.8	"	5.92	.58	8.22
A-933	"	S	E	"	6467	"	"	149.7	4	"	62.3	.337	5.56	5.37	2.49	35.03	6.0	.030	.0125	2.40	8.9	"	5.45	.49	7.66
B-686	"	N	"	"	"	"	"	"	"	"	"	.320	5.29	5.48	2.49	35.05	"	.045	.0125	3.60	14.0	"	5.18	.73	7.63
B-689	"	N	"	"	6466	"	"	116.4	5	"	"	.378	6.24	5.14	2.62	37.03	"	.030	.0138	2.18	7.9	"	6.11	.48	8.31
A-936	"	S	"	"	"	"	"	"	"	"	"	.339	5.60	5.36	2.62	37.03	"	.026	.0138	1.88	7.7	"	5.49	.42	7.63
B-673	"	"	W	"	"	"	"	157.6	6	"	63.9	.321	5.30	5.48	3.50	49.50	7.6	.040	.0246	1.63	12.5	"	5.20	.65	7.57
A-921	"	"	"	"	"	"	"	"	"	"	"	.364	6.00	5.22	3.52	49.63	7.6	.046	.0250	1.84	12.6	"	5.89	.74	8.35
A-908	"	S	E	"	6466	1603	274.0	89.0	6	P	62.3	.371	6.12	5.18	3.60	50.85	6.0	.050	.0260	1.92	13.5	"	6.00	.81	8.53
B-659	"	N	"	"	"	"	"	"	"	"	"	.363	5.99	5.22	3.60	50.85	"	.064	.0260	2.46	17.6	"	5.87	1.03	8.62
A-963	"	S	W	"	6463	"	"	155.4	4	"	63.9	.377	6.22	5.15	3.65	51.50	7.6	.073	.0268	2.72	19.4	"	6.10	1.18	9.00
B-716	"	N	"	"	"	"	"	"	"	"	"	.342	5.65	5.35	3.66	51.60	"	.104	.0270	3.86	30.4	"	5.54	1.68	8.94
A-104	1	N	E	"	6461	"	"	118.9	8	"	62.3	.343	5.66	5.34	3.67	51.90	6.0	.052	.0271	1.92	15.2	"	5.55	.84	8.11

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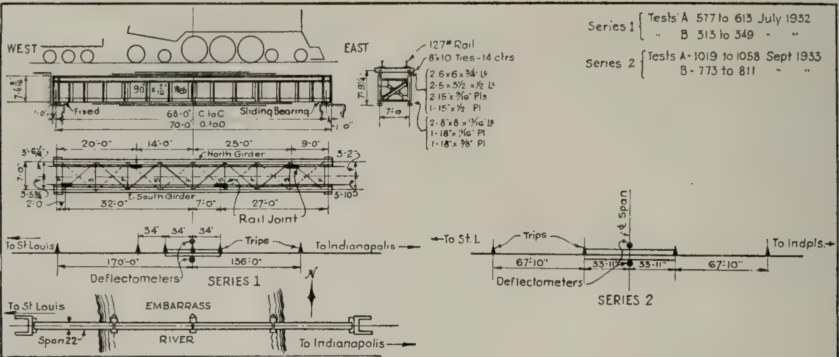
Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D	E.U.L.L (Kips)	Loaded Frequency "n"	R.P.S "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	DL	LL	Imp	Total
A-103	1	N	W	K3K	6463	1603	274.0	157.1	6	P	63.9	.353	5.83	5.29	3.75	52.90	7.6	.059	.0283	2.08	16.7	1.72	5.71	.95	8.38
B-674	2	N	E	"	6468	1603	274.0	108.9	"	"	62.3	.346	5.71	5.32	3.76	53.03	6.0	.062	.0285	2.18	17.9	"	5.60	1.00	8.32
A-922	"	S	"	"	"	"	"	"	"	"	"	.348	5.75	5.31	3.76	53.15	"	.052	.0285	1.82	14.9	"	5.63	.84	8.19
B-702	"	N	W	"	"	"	"	157.6	7	"	63.9	.372	6.14	5.18	3.78	53.45	7.6	.055	.0288	1.91	14.8	"	6.02	.89	8.63
A-949	"	S	"	"	"	"	"	"	"	"	"	.382	6.30	5.13	3.79	53.50	"	.061	.0290	2.10	16.0	"	6.18	.99	8.89
B-658	2	N	"	"	6468	"	"	154.2	4	"	"	.351	5.80	5.30	4.24	59.90	"	.087	.0361	2.41	24.8	"	5.68	1.41	8.81
A-907	"	S	"	"	"	"	"	"	"	"	"	.366	6.07	5.21	4.24	59.90	"	.096	.0361	2.66	26.2	"	5.92	1.55	9.19
				Average	11 Tests Westward						63.9	.361	5.95	5.24			7.6					1.72	5.85		
				"	9 " Eastward						62.3	.349	5.77	5.30			6.0					1.72	5.65		
A-105	1	N	E	KN	6449	1200	246.0	131.7	8	P	63.5	.310	5.11	5.17	2.83	37.84	8.1	.023	.0121	1.90	7.4	1.72	5.02	.37	7.11
B-682	2	N	W	H10A II	152	1390	335.0	256.0	76	F	68.3	.425	7.01	4.83	2.50	28.06	12.8	.020	.0108	1.85	4.7	1.72	6.88	.32	8.92
A-929	"	S	"	"	"	"	"	"	"	"	"	.412	6.80	4.90	2.49	27.95	"	.028	.0108	2.59	6.8	"	6.67	.45	8.84
A-97	1	N	"	H10A III	178	1280	"	207.3	44	"	65.5	.442	7.30	4.76	2.71	31.17	9.4	.046	.0117	3.94	10.4	"	7.15	.74	9.61
A-957	2	S	"	H10A II	134	1390	"	252.5	84	"	68.3	.430	7.10	4.81	2.85	32.07	12.8	.058	.0141	4.11	13.5	"	6.95	.94	9.61
B-710	"	N	"	"	"	"	"	"		"	"	.423	6.98	4.85	2.86	32.20	"	.050	.0142	3.52	11.8	"	6.85	.81	9.38
B-704	"	N	"	"	155	"	"	257.4	7	"		.425	7.01	4.83	3.80	42.70	"	.045	.0250	1.80	10.6	"	6.88	.73	9.33
A-951	"	S	"	"	"	"	"	"	"	"	"	.416	6.86	4.87	3.80	42.80	"	.042	.0250	1.68	10.1	"	6.74	.68	9.14
B-661	2	N	"	H10A II	140	1390	"	231.6	26	"	68.3	.428	7.06	4.82	3.80	42.70	12.8	.042	.0250	1.68	9.7	"	6.92	.67	9.31
A-909	"	S	"	"	"	"	"	"	"	"	"	.326	5.38	5.36	3.83	43.05	"	.045	.0254	1.77	13.8	"	5.28	.73	7.73
B-690	"	N	"	"	155	"	"	266.7	25	"	"	.431	7.11	4.81	3.85	43.30	"	.040	.0256	1.56	9.3	"	6.98	.65	9.35
A-937	"	S	"	"	"	"	"	"	"	"	"	.427	7.05	4.82	3.86	43.36	"	.053	.0258	2.06	12.4	"	6.91	.86	9.49
A-923	"	S	"	"	134	"	"	252.8	16	"	"	.423	6.98	4.85	3.98	44.65	"	.057	.0275	2.07	13.5	"	6.85	.93	9.50
B-675	"	N	"	"	"	"	"	"	"	"	"	.443	7.31	4.75	3.98	44.65	"	.048	.0275	1.74	10.8	"	7.16	.77	9.65

Sheet 7 Span 21

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact γ	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-936	2	S	W	H10A III	170	1280	335.0	234.2	28	F	65.5	418	690	487	404	4539	9.4	.040	0163	2.45	96	172	676	65	915
B-691	"	N	"	"	"	"	"	"	"	"	.	.489	806	451	404	4539	-	.030	0163	184	61	"	790	48	1010
A-965	-	S	-	H10A II	155	1390	-	262.0	15	"	68.3	411	679	490	405	4570	128	060	.0285	210	146	.	665	97	934
B-718		N	-	"	-	.	"	-	"	"	.	411	679	4.90	405	4570	-	.054	.0285	190	131	.	665	.87	924
B-660	"	N	-	"	155	-	"	2643	4	.	.	.423	698	485	408	4586	"	.032	.0289	111	76	.	685	52	909
				Average	18	Tests	Westward				678	.422	697	485			122					172	684		
B-668	2	N	W	H10B I	228	1188	334.5	2386	73	F	659	.422	696	484	192	2153	130	.020	.0053	377	47	172	684	.32	888
A-916	-	S	.	-	.	.	.	-	-	.	-	411	679	489	193	2168	"	.020	.0054	3.70	49	"	665	.33	870
B-698	"	N	.	"	235	-	-	2530	71	"	.	413	681	488	1.94	21.85	.	012	.0055	218	2.9	-	668	.19	859
A-945	-	S	-	.	"	"	"	"	.	"	.	415	685	486	1.95	21.95	"	025	.0055	455	60	-	671	40	883
B-706	-	N	.	-	227	"	"	220.2	39	-	-	396	654	495	243	2736	-	.026	0086	302	66	"	640	42	8.54
A-953	-	S	-	"	-	"	-	"	.	-	.	419	6.91	485	246	2767	"	029	.0088	3.30	69	"	678	47	897
A-924	"	S	-	-	222	-	"	238.8	16	-	"	.404	667	492	286	32.17	"	034	.0118	2.88	84	-	653	55	8.80
B-676	"	N	"	-	222	"	"	"	.	.	"	.434	716	479	287	3227	"	.032	.0119	2.69	74	.	702	.52	926
				Average	8	Tests	Westward				65.9	.414	684	487			13.0					1.72	6.70		
A-967	2	S	W	H7E I	6191	2455	328.0	135.9	0	F	624	377	622	4.99	292	3287	70	081	.0260	312	21.5	172	610	1.31	9.13
B-720	-	N	"	.	"	"	-	"	"	"	-	.413	6.81	4.82	2.96	33.22	-	.081	.0267	3.04	19.6	"	6.68	1.31	9.71
				Average	2	Tests	Westward				62.4	.395	6.52	4.90			7.0					1.72	6.39		
B-711	2	N	E	H6A	6097	2136	290.8	76.6	46	F	61.2	388	640	4.93	1.76	1983	78	025	.0081	309	64	1.72	6.28	.40	840
A-958	"	S	"	-	"	"	-	"	"	"	"	380	627	497	178	20.00	"	016	.0083	193	4.2	"	615	26	813

Sheet 8 Span 21

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact γ	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)				D L.	L L.	Imp	Total
B-681	2	N	E	H6A	6097	2136	290.8	76.6	–	F	61.2	378	624	498	191	2152	7.8	.026	.0096	271	69	172	611	42	825
A-928	-	S	-	"	-	–	"	.	–	.	.	.389	642	4.92	192	2153	"	018	.0097	186	46	"	630	.29	831
A-915	.	S	W	"	6108	"	"	174.0	33	-	64.8	.370	6.10	5.00	230	2580	114	.025	.0139	180	68	.	599	41	812
B-667	-	N	.	"	-	-	"	"	-	.	"	.377	622	497	2.34	26.26	"	.031	.0144	215	82	"	610	.50	8.32
				Average	2	Tests	Westward				64.8	.374	616	4.98			11.4					172	604		
				"	4	"	Eastward				61.2	.384	6.33	4.95			78					172	621		
A-101	1	N	E	H5T	6079	2092	2855	1077	55	F	615	.348	5.75	5.00	196	2208	66	019	0100	190	55	172	563	31	766
A-107	1	N	E	H5LA III	6147	2092	2778	134.9	17	F	658	.351	580	5.00	205	2303	10.9	020	0110	182	57	172	568	32	772
A-96	1	N	W	H5LA I	6145	2092	277.8	129.4	3	F	652	.382	630	500	362	4075	103	.052	0341	152	150	172	618	93	883



DESIGN DATA

Date 1906 Spec. 1901
Material O.H. Steel
Loading E-51.9 E.U.L.L. 7280

Flange Stress	D.L.	1380
(Tens. N. Sec.)	L.L.	6450
	Imp.	830
	Total	8660

Gross M. of I. at Center	433580
Weight Steel per Ft.	1075
Weight Deck per Ft.	470
Total per Ft.	1545
Total for Span	108100

COMPUTED DEFLECTION
(from gross M. of I.)

For 1000 Lbs. per Ft. Trk.	.0412
For 1000 Lbs. at Center	.00166
D.L. Deflection	.0637
D.L. Frequency	13.45

COMPUTED FROM TESTS
(using Aver. M. of I. 395570)

Deflec. 1000 Lbs. per Ft. Trk.	.0452
Deflec. 1000 Lbs. at Center	.00182
Deflec. D.L.	.0698
Frequency D.L.	12.85

$\frac{\text{Average Observed M. of I.}}{\text{Comp. Gross M. of I.}} = .912$

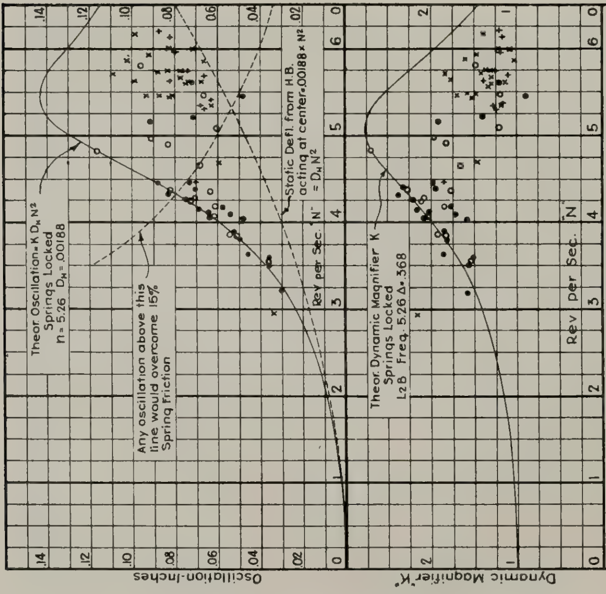
NOTE· Girders were designed for Concrete deck which was not built.

LOCOMOTIVES USED IN TESTS

Class of Engines	K5-A	K5-B (I)	K5-B (II)	J1-D	J1-E	KK	K3R			
Engines per class	1	1	1	5	10	1	1			
Tests per class	2	2	2	20	42	4	4			
Class of Engines	H5L I	L2B	L2-D							
Engines per class	1	8	11							
Tests per class	2	32	42							

SPAN 22
Bridge 272 St Louis Div.
West Span Single Track
70'-0" Deck Plate Girder.

Fig. 64



Engine Class	Static H.B. Defl. I.R.P.S. "D_H"	Assumed Loaded Freq. "n"	Damping Factor "Δ"
○ L2B	.00188	5.26	.368
● L2D	.00218	5.26	.368
+ J1D	.00175	5.29	.370
× J1E	.00172	5.30	.371

NOTE: Oscillations are all plotted for L2B Engines Freq. "n" = 5.26
Frequencies are 98% of theoretical
D.L. Defl. "d" = .0698
Damping Constant p = .035
Damping Factor "Δ" = 2pn = .368

SPAN 22
DECK PLATE GIRDER
70'-0" 0. to 0. 68'-0" c. to c.

Fig. 65

TABLE XXXVI

BRIDGE 272 ST. LOUIS DIV. 70'-0" D. P. GIRDER

Sheet 1 Span 22

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "k"	Impact γ	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1 R.P.S.	Weight (Kips)		No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H.	Dist "H" (Ft.)	Oscil (ins)				DL	LL	Imp	Total
							Eng	Tender																	
B 810	2	N	E	J1E	6628	1672	351.5	290.0	12	P	59.3	.339	7.50	5.29	2.93	41.29	6.1	.030	.0148	2.03	8.9	1.38	6.13	.55	8.06
A-1057	-	S	..	..	6628	-	-	-	-	-	59.3	.291	6.44	5.64	2.94	41.42	6.1	.032	.0149	2.15	11.0	-	5.25	.58	7.21
B-780	-	N	·	·	6628	-	-	..	10	-	59.3	.365	8.08	5.13	4.68	66.00	6.1	.055	.0377	1.46	15.0	·	6.60	.99	8.97
A-1026	-	S	·	-	6628	-	-	-	-	-	59.3	.286	6.33	5.68	4.70	66.30	6.1	.036	.0380	0.95	12.6	..	5.16	.65	7.19
A-1036	..	S	..	-	6625	..	-	294.0	10	..	59.3	.268	5.93	5.81	5.33	75.11	6.1	.041	.0490	0.84	15.3	..	4.85	.74	6.97
B-789	-	N	-	-	6625	-	-	·	..	-	59.3	.370	8.19	5.10	5.36	75.60	6.1	.058	.0495	1.17	15.7	-	6.69	1.05	9.12
A-1040	-	S	W	-	6627	-	-	243.5	13	-	58.9	.309	6.84	5.49	5.41	76.31	5.7	.076	.0505	1.50	24.6	..	5.59	1.38	8.35
B 793	-	N	·	-	6627	-	-	..	-	·	58.9	.316	7.00	5.44	5.44	76.75	5.7	.052	.0510	1.02	16.4	..	5.71	.94	8.03
A-1046	-	S	E	·	6628	-	-	294.0	10	-	59.3	.292	6.46	5.63	5.45	76.82	6.1	.052	.0511	1.02	17.8	-	5.27	.94	7.59
B-799	..	N	·	-	6628	..	-	..	-	-	59.3	.364	2.83	5.13	5.46	77.00	6.1	.087	.0515	1.69	24.0	-	6.58	1.58	9.54
A-1021	-	S	W	..	6625	-	-	270.0	13	-	58.9	.301	6.66	5.55	5.46	77.00	5.7	.075	.0515	1.46	25.0	-	5.44	1.36	8.18
B-775	-	N	-	-	6625	-	-	..	-	-	58.9	.325	7.20	5.38	5.46	77.02	5.7	.047	.0515	0.91	14.5	-	5.87	.85	8.10
A-1035	-	N	·	-	6628	·	-	250.5	11	·	58.9	.312	6.90	5.47	5.47	77.18	5.7	.081	.0516	1.57	26.0	-	5.64	1.47	8.49
A-1045	-	N	-	-	6625	·	-	247.0	11	-	58.9	.299	6.62	5.58	5.58	78.65	5.7	.070	.0535	1.31	23.5	-	5.40	1.27	8.05
B-787	..	N	E	-	6627	-	-	294.0	11	-	59.3	.365	8.08	5.13	5.57	78.48	6.1	.069	.0534	1.29	18.9	-	6.60	1.25	9.23
A-1033	·	S	-	-	6627	-	-	-	-	-	59.3	.262	5.80	5.86	5.62	79.22	6.1	.035	.0544	0.64	13.4	-	4.74	.64	6.76
A-602	1	S	-	-	6620	·	-	290.0	12	-	59.3	.254	5.62	5.93	5.60	78.97	6.1	.032	.0540	0.59	12.6	-	4.59	.58	6.55
B-338	-	N	-	-	6620	-	-	-	-	-	59.3	.355	7.87	5.18	5.62	79.21	6.1	.062	.0544	1.14	17.5	-	6.41	1.12	8.91
B-337	-	N	W	-	6622	-	-	275.0	11	-	58.1	.327	7.24	5.36	5.62	79.17	4.9	.059	.0544	1.09	18.0	-	5.90	1.06	8.34
A-601	-	S	-	-	6622	·	-	-	-	-	58.1	.317	7.02	5.43	5.66	79.77	4.9	.092	.0552	1.76	28.7	-	5.73	1.64	8.75
A-589	-	N	E	-	6621	-	-	294.0	11	-	59.3	.360	7.97	5.16	5.66	79.80	6.1	.072	.0552	1.30	20.0	-	6.50	1.30	9.18
B-325	-	S	-	-	6621	·	-	-	-	-	59.3	.293	6.49	5.63	5.68	80.12	6.1	.039	.0556	0.70	13.4	-	5.30	.71	7.39
A-580	-	N	-	-	6628	-	-	287.0	11	-	59.3	.360	7.97	5.16	5.66	79.80	6.1	.101	.0552	1.83	28.1	·	6.50	1.83	9.61
B-316	-	S	..	-	6628	-	-	-	-	-	59.3	.271	6.00	5.78	5.73	80.72	6.1	.076	.0565	1.35	28.1	-	4.90	1.74	7.92

Sheet 2 Span 22

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "k"	Impact γ	Moment Unit Stress (Kips) Tens. Net Sec			
No	Series			Class	Eng No	H B at 1 RPS	Weight (Kips)		No	Kind	at Dist "P"	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)				DL	LL	Imp	Total
							Eng	Tender																	
B-804	2	N	W	J1E	6628	1672	351.5	247.5	13	P	58.9	.312	6.90	5.47	5.70	80.33	5.7	.042	.0559	.75	13.4	1.38	5.64	.76	7.78
A 1051	·	S	·	-	6628	-	-	..	-	-	58.9	.318	7.04	5.43	5.74	80.87	5.7	.080	.0567	1.41	25.2	-	5.75	1.45	8.58
B 334	1	N	E	·	6629	-	·	294.0	12	-	59.3	.369	8.18	5.11	5.70	80.40	6.1	.072	.0559	1.29	19.5	·	6.67	1.30	9.35
A-598	·	S	·	-	6629	-	-	-	·	-	59.3	.270	5.98	5.79	5.75	81.05	6.1	.039	.0569	.68	14.4	-	4.88	.70	6.96
A-591		N	W	·	6623	·	..	275.0	11	·	58.9	.307	6.80	5.50	5.74	80.96	5.7	.077	.0567	1.36	25.0	·	5.55	1.39	8.32
B 327	·	S	..	·	6623	-	·	-	..	·	58.9	.333	7.37	5.33	5.74	80.99	5.7	.073	.0567	1.29	22.0	·	6.02	1.33	8.73
A-608	-	S	E	·	6628	·		294.0	11	..	59.3	.287	6.35	5.68	5.84	82.30	6.1	.034	.0586	.58	11.8		5.19	.61	7.18
B-344	-	N	..	·	6628	·	-	·	-	..	59.3	.357	7.90	5.17	5.87	82.79	6.1	.061	.0594	1.01	18.0	·	6.45	1.16	8.99
A-582	·	N	W	-	6626	·	·	269.0	11	·	58.9	.307	6.80	5.50	5.83	82.15	5.7	.081	.0585	1.38	26.3	·	5.55	1.46	8.39
B-318	-	S	·	-	6626	..	·	·	·	-	58.9	.333	7.37	5.33	5.89	83.09	5.7	.095	.0596	1.59	28.5	·	6.02	1.72	9.12
A 612	-	S	-	·	6626	-	·	275.0	11	·	58.9	.335	7.42	5.31	5.87	82.99	5.7	.086	.0594	1.45	25.6	·	6.05	1.55	8.98
B 348		N	..	·	6626	·	·	·			58.9	.324	7.17	5.38	5.96	83.99	5.7	.046	.0612	.75	14.2	·	5.85	.83	8.06
A 1025	2	S	·	-	6624	·	·	250.5	10		58.9	.313	6.83	5.46	5.99	84.44	5.7	.066	.0618	1.07	21.0	·	5.65	1.19	8.22
B-779	-	N	..	-	6624	·	·	·	·	·	58.9	.329	7.29	5.35	5.99	84.44	5.7	.058	.0618	.94	17.6	·	5.94	1.04	8.36
A-1055	-	S	-	·	6626	·	-	-	11		58.9	.338	7.48	5.30	5.98	84.27	5.7	.076	.0616	1.23	22.5		6.10	1.37	8.85
B-808	·	N	·	·	6626	·	-	-		·	58.9	.295	6.53	5.61	6.01	84.71	5.7	.047	.0627	.75	16.0	·	5.33	.85	7.56
A-579	1	N	-	·	6629		..	279.0	12		58.9	.302	6.69	5.54	6.14	86.60	5.7	.065	.0634	1.02	21.5		5.46	1.18	8.02
B-315	-	S	·		6629	·	-	-	-	·	58.9	.353	7.81	5.20	6.19	87.31	5.7	.091	.0660	1.38	25.8		6.38	1.65	9.41
		Average 12 Tests No Girder Westward									58.8	.313	6.83	5.45			5.6					1.38	5.65		
			·	10	· S	·					58.8	.325	7.20	5.37			5.6					·	5.87		
			..	10	- N	-		Eastward			59.3	.360	7.96	5.15			6.1					·	6.51		
			..	10	· S	·		·			59.3	.277	6.13	5.73			6.1					·	5.01		

Sheet 3 Span 22

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "k"	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No	H B at 1RPS	Weight (Kips)		No	Kind	at Dist "P"	Defl (ins) D			R.P.S. "N"	M.P.H	Dist H (Ft)	Oscil (ins)							
							Eng	Tender														DL	LL	Imp	Total
A-1023	2	S	E	J1D	6607	1691	353.0	2905	11	P	593	.275	609	570	4.43	6247	61	.035	.0343	102	127	138	497	.63	6.98
B-777	"	N	"	"	6607	"	"	"	"	"	59.3	.364	8.06	5.09	4.49	6335	6.1	065	.0353	1.84	179	"	658	118	9.14
B-319	1	S	"	"	6613	"	"	2875	13	"	59.3	.264	585	5.80	5.30	7478	6.1	028	0492	.57	106	"	477	.51	666
A-583	"	N	"	"	6613	"	"	"	"	"	593	.348	7.48	5.19	5.31	7482	61	.061	.0495	1.23	175	"	629	110	877
A-1041	2	S	"	"	6611	"	"	2940	10	"	59.3	.270	5.97	5.75	5.33	75.09	61	037	.0498	.74	137	"	488	67	693
B-794	"	N	"	"	6611	"	"	"	"	"	593	.387	8.57	4.96	5.34	75.23	6.1	.063	.0499	126	163	"	699	114	951
A-592	1	N	"	"	6611	"	"	"	13	"	593	.331	733	529	535	7537	61	.041	.0501	88	124	"	598	.74	8.10
B-328	"	S	"	"	6611	"	"	"	"	"	593	286	6.10	561	5.37	75.73	61	.058	.0506	115	203	"	5.17	105	760
B-806	2	N	"	"	6600	"	"	"	10	"	593	.370	8.20	5.05	5.62	7928	61	.076	.0553	1.37	205	"	669	137	944
A-1053	"	S	"	"	6600	"	"	"	"	"	59.3	.259	573	5.84	5.63	79.40	61	.051	.0555	.92	197	"	468	.92	698
A-613	1	S	"	"	6613	"	"	"	13	"	59.3	.250	5.53	5.92	5.67	7997	61	061	.0564	1.10	24.3	"	452	110	7.00
B-349	"	N	"	"	6613	"	"	"	"	"	59.3	355	7.86	5.14	567	8000	61	.059	0564	105	166	"	6.41	106	885
A-1032	2	S	W	"	6611	"	"	267.0	14	"	59.0	.313	693	5.41	5.71	8045	58	.071	.0571	1.24	227	"	565	128	8.31
B-786	"	N	"	"	6611	"	"	"	"	"	590	.318	704	537	576	8119	58	.051	.0583	87	16.1	"	5.75	.93	806
B-333	1	N	"	"	6613	"	"	274.0	11	"	59.0	298	6.60	552	5.94	83.69	5.8	.067	.0614	1.09	225	"	538	121	7.97
A-597	"	S	"	"	6613	"	"	"	"	"	590	.324	7.17	5.35	5.98	8430	5.8	.074	.0626	118	228	"	585	134	857
A-607	"	S	"	"	6610	"	"	268.0	12	"	59.0	.336	7.44	5.26	6.10	86.03	58	.076	.0651	1.17	226	"	6.07	1.37	8.82
B-343	"	N	"	"	6610	"	"	"	"	"	590	324	717	5.35	6.13	86.44	5.8	057	.0659	87	176	"	585	103	8.26
A-588	"	N	"	"	6611	"	"	246.0	11	"	590	.280	6.20	566	6.17	8699	58	.077	.0667	115	27.5	"	5.06	1.39	7.83
B-324	"	S	"	"	6611	"	"	"	"	"	590	.318	7.04	5.37	6.20	8742	58	.081	.0674	120	255	"	5.75	1.47	860
		Average 4 Tests N Girder Westward									59.0	305	675	5.47			5.8					138	5.51		
			"	4	" S	"		"			59.0	323	7.15	5.34			5.8					"	583		
			"	6	" N.	"	Eastward				593	.359	795	5.11			61					"	6.49		
			"	6	" S.	"		"			59.3	.267	5.91	5.77			61					"	483		

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Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H.Blow $D_H N^2$ at Center	Dynamic Magnifier "k"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1RPS	Weight (Kips)		No.	Kind	at Dist "P"	Defl. (ins) "D"			R.P.S. "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)							
							Eng	Tender														D.L	L L	Imp.	Total
A-585	1	N	W	K5A	6529	1558	301.0	242.0	7	P	58.6	.272	6.02	5.79	5.94	83.78	5.4	059	.0565	1.04	21.7	1.38	4.92	1.07	737
B-321	"	S	"	"	"	"	"	"	"	"	60.0	.298	6.60	5.58	6.00	84.62	6.8	.081	.0576	140	27.2	"	5.39	146	823
B-330	1	S	W	K5B II	6524	1560	302.0	239.0	8	P	59.0	.323	7.15	5.40	5.82	82.07	5.8	.076	.0544	1.40	23.5	1.38	5.84	137	859
A-594	"	N	"	"	"	"	"	"	"	"	580	.245	5.43	6.03	5.82	82.11	4.8	.071	.0544	1.30	29.0	"	4.43	1.28	7.09
A-604	1	S	W	K5B I	6507	1560	297.5	229.0	7	P	59.2	.326	722	538	619	8731	6.0	.099	.0615	1.61	30.4	1.38	589	1.79	9.06
B-340	"	N	"	"	"	"	"	"	"	"	580	.226	5.00	6.22	626	88.70	48	065	.0629	1.03	28.8	"	4.08	117	6.63
A-1042	2	S	E	K3R	6502	1463	2780	1675	3	P	62.0	.215	477	6.35	492	6937	91	.025	.0366	.68	116	1.38	389	.45	572
B-795	"	N	"	"	"	"	"	"	"	"	59.0	.335	7.42	5.32	492	69.37	61	.045	.0366	1.23	13.4	"	6.05	.81	8.24
A-1050	"	S	W	"	"	"	"	152.0	3	"	56.0	.277	614	5.75	5.66	79.75	31	045	.0485	.93	163	"	500	.82	720
B-803	"	N	"	"	"	"	"	"	"	"	580	285	6.31	569	5.66	79.78	51	.025	.0485	.52	8.8	"	5.15	.45	6.98
A-1031	2	S	W	K-K	6437	1209	242.0	140.0	8	P	59.0	.219	4.85	6.30	5.13	68.68	74	056	.0327	171	25.6	1.38	3.96	1.02	6.36
B-785	"	N	"	"	"	"	"	"	"	"	59.0	.324	7.17	5.40	515	68.94	7.4	.061	.0329	1.88	18.8	"	5.85	1.10	8.33
A-1022	"	S	E	"	"	"	"	152.0	3	"	600	.209	4.63	6.41	5.31	71.15	8.4	.036	.0351	1.03	17.2	"	3.78	.65	5.81
B-776	"	N	"	"	"	"	"	"	"	"	60.0	.293	6.49	5.12	5.35	71.62	8.4	054	.0355	1.52	18.5	"	5.30	.98	7.66
A-609	1	S	W	H5L I	6036	2092	275.7	123.5	3	P	56.5	.253	5.60	5.97	5.03	56.49	5.3	.056	.0536	1.04	222	1.38	4.57	1.02	697
B-345	"	N	"	"	"	"	"	"	"	"	55.5	274	6.07	5.78	5.06	56.83	4.3	.081	.0543	1.49	29.6	"	4.95	1.47	7.80

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Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact γ	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)				D L	L L	Imp	Total
B-774	2	N	E	L2D	6242	2153	3670	2845	96	F	633	369	817	512	320	3940	7.1	035	0224	156	95	138	666	63	867
A-1020	-	S	-	-	6242	-	-	-	-	-	633	314	695	548	323	3977	7.1	031	.0228	136	99	-	568	56	762
A-1049	-	S	-	-	6229	-	-	2875	96	-	633	294	651	563	349	4300	71	035	.0266	132	119	-	531	63	732
B-802	-	N	-	-	6229	-	-	-	-	-	633	.374	828	510	3.51	4323	71	042	0270	155	10.2		6.76	69	883
B-323	1	S	-	-	6240	-	-	2930	91	-	633	.300	664	568	358	4402	71	040	.0279	143	133		542	72	752
A-587	-	N	-	-	6240	-	-	-	-	-	633	.355	786	520	358	4409	71	042	0279	151	119		641	76	855
A-1027	2	S	-	-	6245	-	-	2600	56	-	633	295	653	562	362	4450	71	036	0287	125	122		533	65	736
B-781	-	N	-	-	6245	-	-	-	-	-	633	381	844	5.05	362	4455	71	.053	0287	185	139		6.89	96	923
B-342	1	N	-	-	6240	-	-	287.0	86	-	633	364	8.06	515	380	4650	7.1	058	0316	184	159	-	6.58	105	901
A-606	-	S	-	-	6240	-	-	-	-	-	633	322	713	5.42	381	4690	71	040	0318	126	124	-	581	.72	791
B-796	2	N	W	-	6243	-	-	213.5	86	-	621	352	780	522	3.88	4775	59	061	0329	185	173		635	110	883
A-1043	-	S	-	-	6243	-	-	-	-	-	62.1	308	682	552	392	4815	59	059	.0337	175	192	-	557	107	802
A-1044	-	S	E	-	6248	-	-	2610	51	-	633	284	629	570	403	4957	71	030	.0354	85	10.6	-	513	54	705
B-797	-	N	-	-	6248	-	-	-	-	-	63.3	379	840	507	403	4964	71	.056	0354	158	148	-	685	101	924
A-1038	-	S	-	-	6227	-	-	2600	25	-	633	.298	660	560	402	4950	71	061	0353	173	205		539	1.10	787
B-791	-	N	-	-	6227	-	-	-	-	-	633	355	786	520	406	5007	71	074	.0360	206	208		641	133	912
B-778	-	N	W	-	6229	-	-	2370	58	-	621	365	809	515	407	5002	59	061	.0362	168	167	-	660	110	908
A-1024	-	S	-	-	6229	-	-	-	-	-	621	297	657	560	409	5007	59	063	0366	172	212		536	114	788
A-1037	-	S	E	-	6247	-	-	293.0	73	-	63.3	303	670	556	405	4975	7.1	055	.0359	153	182		547	100	785
B-790	-	N	-	-	6247	-	-	-		-	63.3	.373	826	510	414	50.93	71	076	0375	203	204		674	138	9.50
B-335	1	N	W	-	6246	-	-	224.0	70	-	621	.351	777	523	407	5005	59	078	0362	216	223	-	634	141	913
A-599	-	S	-	-	6246	-	-	-	-	-	62.1	318	7.04	545	414	5093	59	080	.0375	214	252		575	145	8.58
B-807	2	N	-	-	6249	-	-	234.5	41	-	621	.381	844	5.05	416	5121	59	067	0378	177	176		6.89	1.21	948
A-1054	-	S	-	-	6249	-	-	-	-	-	621	309	6.84	5.51	418	5144	59	056	0381	147	182	-	559	1.01	798

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Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact γ	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)				D L	L L	Imp	Total
A-1028	2	S	E	L2D	6244	2153	3670	2825	56	F	633	298	6.60	560	424	5218	71	054	.0393	1.37	182	1 38	539	98	775
B-782	-	N	-	-	6244	-	-	-	-	-	63.3	357	791	5.19	426	5244	71	087	.0396	220	244	-	645	158	941
B-811	-	N	-	-	6243	-	-	2870	62	-	633	336	7.43	5.33	430	5295	7.1	096	.0404	238	285	-	6.07	173	918
A-1058	-	S	-	-	6243		-	-	-	-	63.3	306	6.78	5.53	431	5300	7.1	046	0406	113	150	-	553	.83	774
B-329	1	S	-	-	6246	-	-	2935	66	-	633	.312	690	550	438	53.88	7.1	.067	0416	1.61	21.5	-	564	1.21	823
A-593	-	N	-	-	6246	-	-	-		-	633	344	7.61	5.27	438	5394	7.1	.081	0416	1.95	235	-	621	146	905
A-603	-	S	-	-	6247	-	-	2940	61	-	63.3	299	6.62	5.59	443	5447	71	.068	.0427	1.59	227	-	540	1.23	801
B-339	-	N	-	-	6247	-	-	-	-	-	633	.369	8.17	5.12	446	54.91	7.1	102	0435	234	277	-	667	185	990
A-584	-	N	-	-	6247	-	-	-	60	-	633	.373	826	510	443	5446	71	.085	0427	199	228	-	674	154	966
B-320	-	S	-	-	6247	-	-	-	-	-	633	.289	640	5.67	447	54.97	71	.067	0436	153	232	-	522	1.21	781
B-341	-	N	W	-	6247	-	-	1610	32	-	621	365	808	515	5.15	6334	5.9	106	0556	191	290	-	659	191	988
A-605	-	S	-	-	6247	-	-	-	-	-	621	292	646	564	515	6342	59	097	0556	174	332	-	527	159	824
A-586	-	N	-	-	6242	-	-	1820	39	-	621	346	767	526	521	6406	59	.076	0593	128	220	-	625	1.33	901
B-322	-	S	-	-	6242	-		-	-	-	621	.301	666	567	521	6410	59	083	0593	140	275	-	544	150	832
A-596	-	S	-	-	6240	-	-	2600	40	-	621	317	702	545	543	6676	59	.056	.0644	87	177	-	573	101	812
B-332	-	N	-	-	6240	-		-	-	-	621	339	750	531	5.47	6728	59	040	0655	61	118	-	613	72	823
B-313	-	S	-	-	6240	-	-	2650	33		621	320	708	543	558	6865	59	071	0679	105	222	-	579	129	846
A-577	-	N	-		6240	-	-	-	-	-	621	353	782	522	560	6886	59	083	.0685	121	235	-	638	150	926
	Average			8 Tests	No	Girder		Westward			62.1	357	791	519			59					1.38	644		
		-		8 -	So	-					621	308	682	552			59					-	556		
		-		13 -	No	-	Eastward				633	364	806	515			71					-	657		
		-		13 -	So	-		-			633	301	666	557			71						544		

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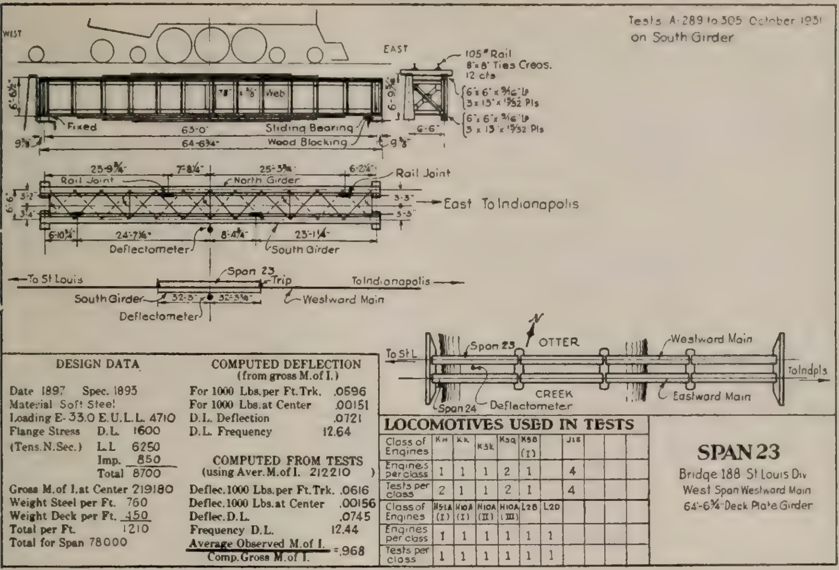
Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat Defl H Blow D×N² at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H.	Dist. "H" (Ft)	Oscil (ins)				D L	L L	Imp	Total
A-1029	2	S	E	L2B	6201	1844	364.0	269.0	96	F	63.2	.293	6.49	5.62	3.53	43.50	7.0	.025	.0235	1.06	8.5	1.38	5.30	.45	7.13
B-783	"	N	"	"	6201	"	"	"	"	"	63.2	.359	7.95	5.17	3.53	43.55	7.0	.036	.0235	1.53	10.0	"	6.49	.65	8.52
A-1047	"	S	"	"	6205	"	"	"	66	"	63.2	.312	6.91	5.47	3.82	47.05	7.0	.030	.0275	1.09	9.6	"	5.64	.54	7.56
B-800	"	N	"	"	6205	"	"	"	"	"	63.2	.373	8.26	5.08	3.85	47.35	7.0	.051	.0279	1.83	13.7	"	6.74	.92	9.04
B-809	"	N	"	"	6208	"	"	240.0	44	"	63.2	.370	8.19	5.10	3.85	47.45	7.0	.054	.0279	1.93	14.6	"	6.69	.98	9.05
A-1056	"	S	"	"	6208	"	"	"	"	"	63.2	.293	6.49	5.62	3.86	47.55	7.0	.036	.0280	1.28	12.3	"	5.30	.65	7.33
B-805	"	N	"	"	6202	"	"	269.0	95	"	63.2	.356	7.88	5.19	4.04	49.75	7.0	.062	.0307	2.02	17.4	"	6.44	1.12	8.94
A-1052	"	S	"	"	6202	"	"	"	"	"	63.2	.294	6.51	5.61	4.08	50.25	7.0	.025	.0314	.80	8.5	"	5.31	.45	7.14
A-1039	"	S	W	"	6201	"	"	243.0	64	"	62.2	.290	6.42	5.70	4.17	51.28	6.0	.051	.0327	1.56	17.6	"	5.24	.92	7.54
B-792	"	N	"	"	6201	"	"	"	"	"	62.2	.358	7.93	5.23	4.18	51.45	6.0	.061	.0329	1.85	17.1	"	6.46	1.10	8.94
A-595	1	S	E	"	6208	"	"	278.0	30	"	63.2	.302	6.69	5.55	4.24	52.10	7.0	.070	.0338	2.07	23.2	"	5.46	1.27	8.11
B-331	"	N	"	"	6208	"	"	"	"	"	63.2	.381	8.44	5.03	4.29	52.35	7.0	.073	.0346	2.11	19.1	"	6.89	1.32	9.59
B-326	"	S	"	"	6200	"	"	277.5	38	"	63.2	.289	6.40	5.65	4.27	52.49	7.0	.059	.0343	1.72	20.4	"	5.22	1.07	7.67
A-590	"	N	"	"	6200	"	"	"	"	"	63.2	.350	7.75	5.22	4.27	52.59	7.0	.071	.0343	2.07	20.2	"	6.33	1.28	8.99
A-1034	2	S	W	"	6205	"	"	214.5	62	"	62.2	.310	6.87	5.55	4.36	53.62	6.0	.063	.0357	1.76	20.3	"	5.60	1.14	8.12
B-788	"	N	"	"	6205	"	"	"	"	"	62.2	.365	8.08	5.19	4.36	53.69	6.0	.051	.0357	1.43	14.0	"	6.60	.92	8.90
A-581	1	N	E	"	6203	"	"	264.0	11	"	63.2	.340	7.53	5.28	4.37	53.80	7.0	.082	.0360	2.28	24.1	"	6.15	1.48	9.01
B-317	"	S	"	"	6203	"	"	"	"	"	63.2	.302	6.69	5.55	4.38	53.93	7.0	.056	.0362	1.55	18.5	"	5.46	1.01	7.85
A-1030	2	S	W	"	6203	"	"	256.0	62	"	62.2	.317	7.02	5.50	4.65	57.23	6.0	.057	.0407	1.40	18.0	"	5.73	1.14	8.25
B-784	"	N	"	"	6203	"	"	"	"	"	62.2	.372	8.23	5.14	4.67	57.47	6.0	.068	.0411	1.65	18.3	"	6.72	1.23	9.33
A-610	1	S	"	"	6208	"	"	206.0	65	"	62.2	.287	6.35	5.72	4.81	59.17	6.0	.117	.0436	2.68	40.8	"	5.19	2.12	8.69
B-346	"	N	"	"	6208	"	"	"	"	"	62.2	.330	7.30	5.41	4.85	59.74	6.0	.081	.0443	1.83	24.5	"	5.96	1.46	8.80
A-611	"	S	E	"	6206	"	"	273.0	32	"	63.2	.272	6.02	5.78	4.89	60.14	7.0	.051	.0450	1.13	18.8	"	4.92	.93	7.23
B-347	"	N	"	"	6206		"	"	"	"	63.2	.377	8.35	5.06	4.91	60.42	7.0	.083	.0454	1.83	22.0	"	6.81	1.50	9.69

Sheet 8 Span 22

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow D×N² at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H.	Dist "H" (Ft.)	Oscil (ins)				D L	L L	Imp.	Total
B-801	2	N	W	L2B	6204	1844	364.0	251.0	61	F	62.2	.385	8.30	5.07	4.97	61.10	6.0	.091	.0465	1.96	23.6	1.38	6.95	1.64	9.97
A-1048	"	S	"	"	6204	"	"	"	"	"	62.2	.310	6.87	5.55	4.97	61.21	6.0	.081	.0465	1.74	26.1	"	5.60	1.46	8.44
A-600	1	S	E	"	6201	"	"	277.5	28	"	63.2	.268	5.93	5.82	5.07	62.38	7.0	.037	.0485	.76	13.8	"	4.84	.67	6.89
B-336	"	N	"	"	6201	"	"	"	"	"	63.2	.367	8.12	5.12	5.08	62.46	7.0	.060	.0486	1.23	16.4	"	6.63	1.09	9.10
A-1019	2	S	W	"	6201	"	"	171.0	44	"	62.2	.335	7.42	5.37	5.46	67.16	6.0	.066	.0560	1.18	19.7	"	6.05	1.19	8.62
B-773	"	N	"	"	6201	"	"	"	"	"	62.2	.356	7.88	5.24	5.46	67.16	6.0	.056	.0560	1.00	15.7	"	6.43	1.01	8.82
A-578	1	N	"	"	6204	"	"	193.5	32	"	62.2	.322	7.13	5.46	5.73	70.57	6.0	.077	.0618	1.24	23.9	"	5.81	1.39	8.58
B-314	"	S	"	"	6204	"	"	"	"	"	62.2	.302	6.69	5.61	5.87	72.26	6.0	.096	.0650	1.48	31.8	"	5.45	1.74	8.57
	Average			7 Tests	N.	Girder	Westward					.355	7.86	5.25			6.0					1.38	6.42		
			"	7 "	S.	"		"				.321	7.11	5.46			6.0					"	5.55		
			"	9 "	N.	"	Eastward					.364	8.05	5.13			7.0					"	6.57		
			"	9 "	S.	"		"				.292	6.46	5.62			7.0					"	5.27		

NOTE:- Track is badly off center at East End which accounts for variation in deflections for different direction of movement.



DESIGN DATA

Date 1897 Spec. 1893
Material Soft Steel
Loading E-33.0 E.U.L.L. 4710
Flange Stress D.L. 1600
(Tens.N.Sec.) L.L 6250
Imp. 850
Total 8700
Gross M.of I.at Center 219180
Weight Steel per Ft. 760
Weight Deck per Ft. 450
Total per Ft. 1210
Total for Span 78000

COMPUTED DEFLECTION
(from gross M.of I.)

For 1000 Lbs.per Ft.Trk. .0596
For 1000 Lbs.at Center .00151
D.L. Deflection .0721
D.L. Frequency 12.64

COMPUTED FROM TESTS
(using Aver.M.of I. 212210)

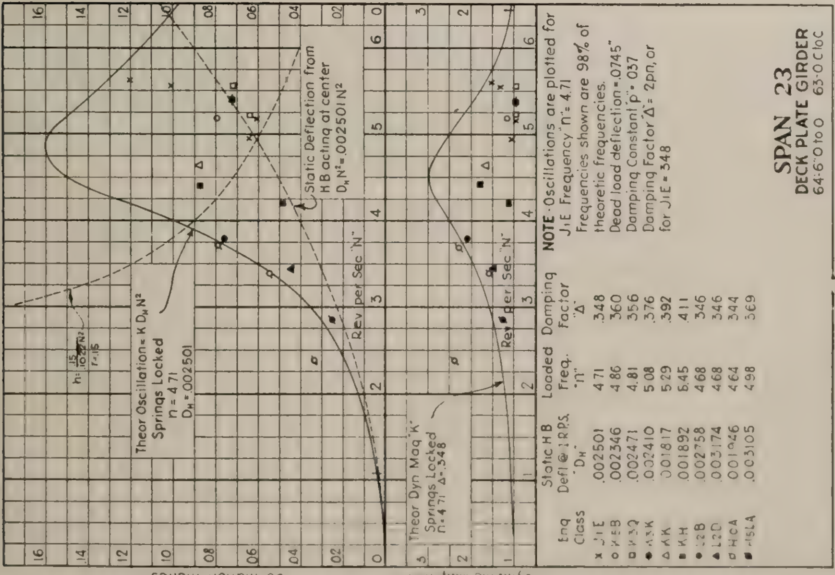
Deflec.1000 Lbs.per Ft.Trk. .0616
Deflec.1000 Lbs.at Center .00156
Deflec.D.L. .0745
Frequency D.L. 12.44

$\frac{\text{Average Observed M.of I.}}{\text{Comp.Gross M.of I.}} = .968$

LOCOMOTIVES USED IN TESTS

Class of Engines	KH	KK	K3k	K3q	K5B (I)		J1E			
Engines per class	1	1	1	2	1		4			
Tests per class	2	1	1	2	1		4			
Class of Engines	H51A (I)	H10A (I)	H10A (II)	H10A (III)	L2B	L2D				
Engines per class	1	1	1	1	1	1				
Tests per class	1	1	1	1	1	1				

Fig. 66



Eng Class	Static H B Defl @ 1 R.P.S. "D_H"	Loaded Freq. "n"	Damping Factor "Δ"
× J1E	.002501	4.71	.348
○ K5B	.002346	4.86	.360
□ K3Q	.002471	4.81	.356
● K3K	.002410	5.08	.376
△ KK	.001817	5.29	.392
■ KH	.001892	6.45	.411
● L2B	.002758	4.68	.346
▲ L2D	.003174	4.68	.346
□ H10A	.001946	4.64	.344
■ H51A	.003105	4.98	.369

NOTE-Oscillations are plotted for J1E Frequency "n" = 4.71
Frequencies shown are 98% of theoretic frequencies.
Dead load deflection = .0745"
Damping Constant "p" = .037
Damping Factor "Δ" = 2pn, or for J1E = .348

SPAN 23
DECK PLATE GIRDER
64'-6" O to O 63'-0" C to C

Fig. 67

TABLE XXXVII

BRIDGE No. 188 ST. LOUIS-DIV. 64'-6" D. P. G. 63'-0" C. to C.

Sheet 1 Span 23

Test		Girder	Direc of Movement	Locomotive					Cars		Stat'l L Defl		E U L L (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R.P.S. "N"	M P H	Dist "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-301	1	S	W	J1E	6624	1672	351.5	185.8	11	P	61.2	.459	7.43	4.69	4.95	69.86	10.5	.064	.0613	1.04	13.9	1.6	9.88	1.37	12.85
A-303	1	"	"	"	6622	"	"	"	10	"	59.4	.438	7.08	4.78	5.17	72.99	8.7	.062	.0667	.93	14.1	"	9.43	1.33	12.36
A-292	1	"	"	"	6629	"	"	"	10	"	59.1	.459	7.43	4.69	5.60	79.23	8.4	.120	.0785	1.53	13.9	"	9.88	1.37	12.85
A-294	1	"	"	"	6623	"	"	"	9	"	62.0	.438	7.08	4.78	5.55	78.31	11.3	.102	.0770	1.33	14.1	"	9.43	1.33	12.36
						Average					60.4	.449	7.26	4.74			9.7					1.6	9.66		
A-290	1	S	W	K5B Type I	6510	1560	297.5	223.2	7	P	58.0	.433	7.00	4.81	5.18	73.05	7.3	.074	.0630	1.17	17.1	1.6	9.31	1.59	12.50
A-299	1	S	W	K3Q	6485	1645	295.5	164.3	7	P	58.5	.413	6.68	4.90	5.22	73.72	8.4	.062	.0670	.93	15.0	1.6	8.88	1.33	11.81
A-295	1	"	"	"	6486	"	"	"	7	"	57.5	.451	7.30	4.73	5.55	78.31	7.4	.071	.0760	.93	15.7		9.70	1.52	12.82
						Average					58.0	.432	6.99	4.82			7.9					1.6	9.29		
A-304	1	S	W	K3K	6465	1603	274.0	160.0	7	P	59.2	.398	6.44	4.98	5.38	75.88	9.1	.069	.0699	.99	17.4	1.6	8.55	1.49	11.64
A-293	1	S	W	KK	6435	1209	242.0	112.6	4	P	58.8	.372	6.03	5.13	4.64	62.07	9.7	.064	.0390	1.64	17.2	1.6	8.00	1.38	10.98
A-296	1	S	E	KH	6425	1260	236.0	93.6	3	P	62.4	.326	5.28	5.40	4.20	56.28	13.3	.037	.0334	1.11	11.3	1.6	7.02	0.79	9.41
A-302	1	S	W	"	"	"	"	"	3	"	58.6	.355	5.75	5.23	4.42	59.23	9.5	.066	.0369	1.79	18.6	"	7.64	1.43	10.67
						Average					60.5	.341	5.52	5.32			11.4					1.6	7.34		
A-300	1	S	W	L2D	6246	2153	367.0	239.7	96	F	60.6	.484	7.83	4.58	3.44	42.36	6.9	.056	.0375	1.49	11.5	1.6	10.41	1.20	13.21
A-297	1	S	W	L2B	6203	1844	364.0	189.3	82	F	59.3	.426	6.89	4.83	3.80	46.80	5.6	.048	.0398	2.11	19.7	1.6	9.16	1.80	12.56

Sheet 2 Span 23

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R.P.S. "N"	M P H	Dist "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-291	1	S	W	H10A Type II	149	1390	335.0	162.1	90	F	55.6	.433	7.01	4.80	2.39	26.82	4.9	.028	.0118	2.37	6.5	1.6	9.31	0.65	11.56
A-305	1	"	"	" " III	172	1280	"	164.4	90	F	56.4	.454	7.34	4.71	3.38	38.01	5.7	.041	.0265	1.55	9.1	"	9.77	0.89	12.26
A-289	1	"	"	" " I	5	1270	"	183.3	85	F	55.2	.459	7.43	4.68	3.71	41.65	4.5	.059	.0258	2.28	12.8	"	9.88	1.26	12.74
						Average					55.7	.449	7.26	4.73			5.0								
A-298	1	S	W	H5LA Type I	6129	2092	277.8	79.2	17	F	56.0	.359	5.80	5.20	2.86	32.17	7.3	.031	.0255	1.22	8.6	1.6	7.72	0.66	9.98

SPAN NO. 24

A deck girder span, 64 ft. 8 in. long over all, and 62 ft. 8 in. center to center of bearings. See Fig. 68.

Readings were taken on this span during the tests on Span 23. The tests are few and at low speeds, but as far as they go, the theoretical and actual oscillations agree closely, as shown in Fig. 69. The damping constant was found to be .036, and the deflection factor to be 1.145.

SPAN NO. 25

A deck girder span, 64 ft. long over all, and 61 ft. 9 in. center to center of bearings. See Fig. 70.

The oscillations, as a result of damping, are quite low, as will be seen in Fig. 71. The damping constant was found to be .0362, which is a little higher than might be expected. The deflection factor is 1.087.

There was some unusual condition at this bridge, causing excessive roll. It will be seen from Table XXXIX that the deflection of one girder, may be as much as 8 to 10 per cent higher or lower than that of the opposite girder for the same pair of tests, while the average of the deflections for the north and south girders, for any one class of engine, is about the same.

SPAN NO. 26

A deck girder span, 53 ft. 3 in. long over all, and 52 ft. center to center of bearings. See Fig. 62.

The west end of this girder was on 8-inch timber blocking, and there was some play under the north bearing.

The theoretical oscillations and magnifiers have been computed for two frequencies, corresponding to the light and heavy locomotives, and are shown in Fig. 73. It will be seen that while some of the oscillations at the high speeds were damped, others attained their theoretical value. From these the damping constant was found to be .0417. The deflection factor is 1.090.

SPANS 27 and 28

Deck girder spans, 50 ft. long over all, and 48 ft. center to center of bearings. While these girders are in different bridges they are duplicate spans, except for the deck construction, and span 28 is carried on 8-inch timber blocking. See Fig. 74 and 75.

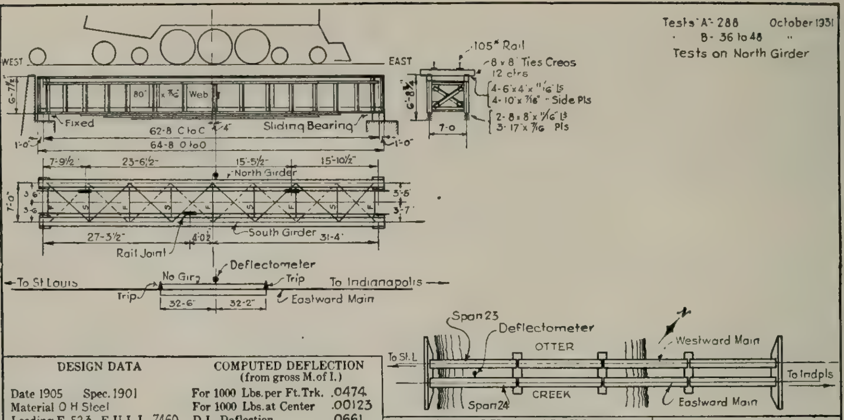
The measured oscillations for both spans have been plotted on Fig. 76. While some of the oscillations have apparently been damped, others seem to be unaffected. The damping constant was found to be .0405, and the deflection factor to be 1.121.

SPAN NO. 29

A deck girder span, 50 ft. long over all, and 48 ft. 4 in. center to center of bearings. See Fig. 77.

The measured and theoretical oscillations are shown on Fig. 78. While many of the oscillations were of sufficient magnitude to overcome spring friction, it would seem that the springs remain locked, except perhaps with the J1-D locomotives.

The damping constant was found to be .0418, and the deflection factor is 1.176. This girder was tested with span No. 19.



DESIGN DATA

Date 1905 Spec. 1901
Material O H Steel
Loading E-523 E.U.L.L. 7460
Flange Stress D.L. 1400
(Tens.N.Sec.) L.L. 7650
Imp. 1050
Total 10100
Gross M.of I.at Center 268840
Weight Steel per Ft. 940
Weight Deck per Ft. 450
Total per Ft. 1390
Total for Span 89,900

COMPUTED DEFLECTION
(from gross M.of I.)

For 1000 Lbs.per Ft.Trk. .0474
For 1000 Lbs.at Center .00123
D.L. Deflection .0661
D.L. Frequency 13.20

COMPUTED FROM TESTS
(using Aver.M.of I. 234800)

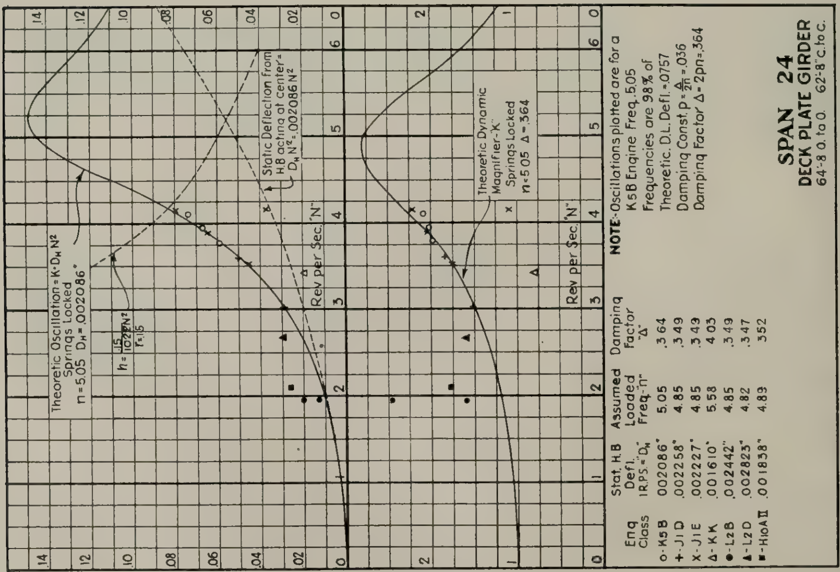
Deflec.1000 Lbs.per Ft.Trk. 0543
Deflec.1000 Lbs.at Center .00141
Deflec.D.L. .0757
Frequency D.L. 12.32
$\frac{\text{Average Observed M.of I.}}{\text{Comp.Gross M.of I.}}$ .873

LOCOMOTIVES USED IN TESTS

Class of Engines	KK	K5A	K5B (I)	K5B (II)	J1D	J1E				
Engines per class	1	1	1	1	2	4				
Tests per class	1	1	1	1	2	4				
Class of Engines	H10A (II)	L2B	L2D							
Engines per class	1	2	1							
Tests per class	1	2	1							

SPAN 24
Bridge 188 St. Louis Div
West Span Eastward Main
64'-8" Deck Plate Girder

Fig. 68



Eng Class	Stat. H.B Defl. 1R.P.S. = "D_H"	Assumed Loaded Freq.-"n"	Damping Factor "Δ"
o - K5B	.002086"	5.05	.364
+ - J1D	.002258"	4.85	.349
x - J1E	.002227"	4.85	.349
Δ - KK	.001610"	5.58	.403
● - L2B	.002442"	4.85	.349
▲ - L2D	.002823"	4.82	.347
■ - H10A II	.001838"	4.89	.352

NOTE:- Oscillations plotted are for a K5B Engine Freq. 5.05
Frequencies are 98% of Theoretic. D.L. Defl. = .0757
Damping Const. $p = \frac{\Delta}{2n} = .036$
Damping Factor $\Delta = 2pn = .364$

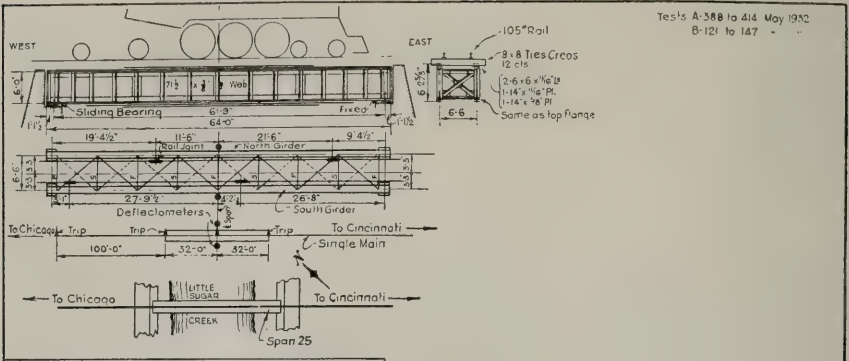
SPAN 24
DECK PLATE GIRDER
64'-8 O. to O. 62'-8" C. to C.

Fig. 69

TABLE XXXVIII

BR No.188 ST LOUIS DIV 62'-8" C. to C. 64'-8" O to O. D P G. Sheet 1 Span 24

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact γ	Moment Unit Stress (Kips) Tens. Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)				DL	LL	Imp	Total
A-288	I	N	E	J1D	6612	1691	353.0	2456	8	P	580	407	746	496	302	4263	75	.031	.0206	152	76	14	753	057	950
B-37	-	-	-	-	6600	-	-	2420	8	-	583	412	7.56	494	360	5085	78	.054	.0293	184	131	-	761	100	10 01
						Average 2 Tests					582	4.095	7.51	4.95			77					1.4	757		
B-39	I	N	E	J1E	6627	1672	3515	2555	10	P	576	.387	711	503	415	5854	71	.041	.0384	107	106	14	716	076	932
B-42	-	-	-	-	6626	-	-	2451	10	-	58.6	407	746	493	352	49.65	81	.048	.0276	174	11.8	-	753	089	982
B-44	-	-	-	-	6628	-	-	2555	10	-	56.4	.417	765	488	415	5850	59	.085	.0384	222	204	-	771	158	1069
B-48	-	-	-	-	6629	-	-	2451	9	-	575	400	735	497	388	5476	70	.069	.0337	204	17.3	-	740	128	1008
						Average 4 Tests					575	403	739	495			70					1.4	745		
B-41	I	N	E	K5B I	6508	1560	2975	229.2	8	P	575	378	695	5.18	379	53.50	7.0	.059	.0300	197	16.6	1.4	699	1.09	948
B-47	I	N	E	K5B II	6519	1560	302.0	229.2	9	P	60.2	.388	7.13	5.15	4.11	57.15	9.7	.074	.0354	208	19.1	1.4	718	137	1135
B-36	I	N	E	K5A	6526	1560	3010	2262	8	P	58.7	.402	7.37	5.10	3.96	55.85	8.2	.066	.0328	201	16.4	1.4	733	120	9.93
B-46	I	N	E	KK	6444	1209	2420	942	3	P	594	316	581	5.70	3.41	4568	10.4	.014	.0188	0.778	44	14	630	0.28	798
B-40	I	N	E	L2B	6205	1844	3640	287.0	68	F	62.7	398	731	4.98	196	2411	92	.015	.0094	1595	3.8	1.4	736	0.28	9.04
B-45		-	-		6206			-	69	-	627	411	755	492	196	2415	92	.023	.0094	245	56	14	759	043	942
				Average	2	Tests						.405	743	495			9.2					1.4	748		
B-38	I	N	E	L2D	6248	2153	3670	3070	54	F	627	420	771	492	267	3280	9.2	.039	.0249	1565	93	14	776	072	988
B-43	I	N	E	H10A II	169	1390	335.0	2713	98	F	63.4	425	780	499	210	2361	143	.023	.0131	1755	54	14	786	043	969



DESIGN DATA

Date 1898 Spec. 1893
Material Soft Steel
Loading E-33. E.U.L.L. 4720
Flange Stress D.L. 1650
(Tens.N.Sec.) L.L. 6220
Imp. 850
Total 8720
Gross M.of I.at Center 194860
Weight Steel per Ft. 800
Weight Deck per Ft. 450
Total per Ft. 1250
Total for Span 80000

COMPUTED DEFLECTION
(from gross M.of I.)

For 1000 Lbs.per Ft.Trk. .0615
For 1000 Lbs.at Center .00159
D.L. Deflection .0768
D.L. Frequency 12.29

COMPUTED FROM TESTS
(using Aver.M.of I. 179270)

Deflec.1000 Lbs.per Ft.Trk. .0668
Deflec.1000 Lbs.at Center .00173
Deflec.D.L. .0835
Frequency D.L. 11.80

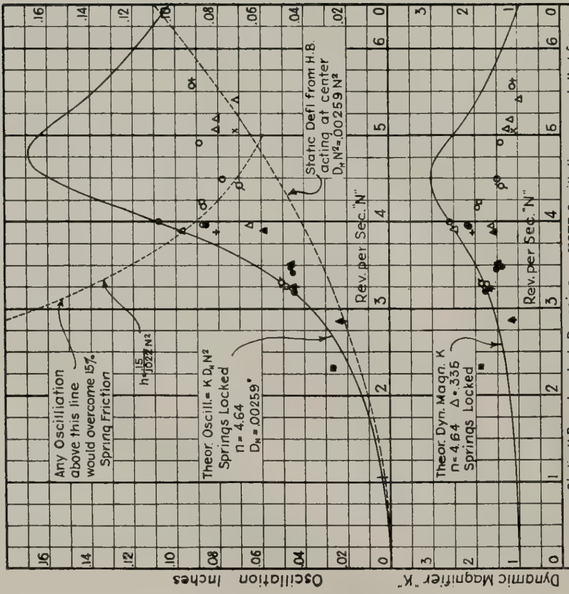
$\frac{\text{Average Observed M.of I.}}{\text{Comp.Gross M.of I.}} = .920$

LOCOMOTIVES USED IN TESTS

Class of Engines	K-B	K-4	K3J K3K	K3Q	K-5	K5-B (I)	K5-B II	J1D		
Engines per class	1	1	2	1	1	4	1	1		
Tests per class	2	2	10	2	4	14	2	2		
Class of Engines	H5LA I	H7E V	L2B	L2D						
Engines per class	1	2	3	1						
Tests per class	4	4	6	2						

SPAN 25
Bridge 431 Chicago Div.
Single Track
64'-0" Deck Plate Girder

Fig. 70



Eng. Class	Static H.B. Defl @ 1 R.P.S. "D_H"	Loaded Freq. "n"	Damping Factor "Δ"
o K3B	.00259"	4.64	.335
+ K5	.00277"	4.64	.335
x J1D	.00282"	4.45	.322
◻ K3Q	.00272"	4.62	.334
Δ K3K	.00265"	4.82	.348
◻̸ KB	.00209"	5.08	.367
● L2B	.00307"	4.35	.315
■ L2D	.00352"	4.35	.315
▲ H7EV	.00404"	4.35	.315
◆ H5LAI	.00344"	4.83	.349

NOTE Oscillations are plotted for K5B Freq. "n" = 4.64
Frequencies shown are 98.3% of theor. frequencies
Dead load deflection = .0835"
Damping Constant "p" = .0362
Damping Factor "Δ" = 2pn K5B = .335

SPAN 25
DECK PLATE GIRDER
64'-0" 0.to 0. 61'-9" C.to C.

Fig. 71

TABLE XXXIX

BR No. 431 CHICAGO DIV. 64'-0" D P G - 61'-9" C to C BEARINGS

Sheet 1 Span 25

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"	E.U.L.L (Kips)	Loaded Frequency 'n'	R.P.S. "N"	M.P.H.	Dist "H" (Ft)	Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	D L	L L	Imp	Total
A-413	I	S	W	J1D	6605	1690	3530	211.0	9	P	568	460	689	4.49	502	7076	68	.074	0712	104	16.1	165	909	146	1220
B-146	-	N	"	"	"	"	"	"	-	"	"	448	670	454	503	70.86	68	.078	0716	109	191	·	885	169	12.19
						Average						454	6.80	452			68					165	896		
A-397	I	S	W	K5	6525	1670	303.0	2505	12	P	572	469	702	464	3.89	5485	7.2	.087	.0420	207	186	1.65	926	171	1262
B-130	-	N	-	-	-	"	-	-	"	"	"	435	651	480	387	5462	7.2	.067	.0415	161	154	"	860	132	1157
A-393	-	S	E	-	6525	-	-	203.5	8	"	58.8	435	651	480	5.70	8045	88	.098	.0903	108	225	·	8.60	193	12.18
B-126	-	N	"	-	"	"	"	"	"	-	"	469	7.02	464	555	78.33	88	079	.0827	.95	16.8	"	926	155	1246
					Average N.		Girder				58.0	452	6.77	472			80					165	8.93		
					"	S.	Girder				580	452	6.77	472			8.0					165	8.93		
A-396	I	S	W	K5B-I	6505	1560	297.5	171.0	3	P	56.0	447	6.70	474	327	46.15	60	046	0277	166	10.3	165	884	0.91	1140
B-129	-	N	-	"	-	"	"	-	"	-	-	433	6.49	481	3.27	4615	60	.049	.0277	177	11.3	-	8.56	098	1119
A-407	"	S	W	"	6509	-	"	250.5	10	·	57.2	485	726	4.59	3.96	5585	72	.086	0406	212	177	"	9.59	1.70	1294
B-140	·	N	·	"	-	"	-	-	"	-	"	.429	6.42	4.82	3.97	55.91	72	.056	0409	137	131	-	8.48	1.11	1124
A-392	"	S	W	-	6505	-	"	201.0	7	"	56.0	460	689	4.69	3.96	5587	6.0	087	.0406	2.14	189	"	9.09	172	12.46
B-125	"	N	-	-	"	"	·	"	"	"	"	.434	650	480	396	55.91	60	.080	.0406	1.97	18.4	"	858	158	11.81
A-388	"	S	W	-	6506	·	"	250.5	10	-	57.2	.435	6.51	4.80	4.00	5645	7.2	.108	0415	260	248	-	8.60	213	12.38
B-121	·	N	-	"	-	"	"	"	"	"	-	.454	6.80	4.76	400	5650	7.2	.087	.0415	210	19.2	"	8.96	1.71	1232
A-412	-	S	W	K5B II	6517	-	3030	244.0	6	"	571	.452	6.77	472	4.16	58.64	7.1	.087	.0448	194	192	"	894	172	12.31
B-145	-	N	"	"	"	"	"	-	"	"	"	421	630	4.86	417	58.76	71	.074	.0452	1.64	176	"	8.32	146	1143
A-404	·	S	E	K5B I	6514	-	297.5	2530	5	"	572	.445	666	476	449	6333	72	.077	0523	1.47	17.3	-	880	152	1197
B-137	"	N	-	"	"		"	-	-	"	"	.466	6.98	466	448	63.17	72	.078	0521	149	16.7	-	920	154	1239

Sheet 2 Span 25

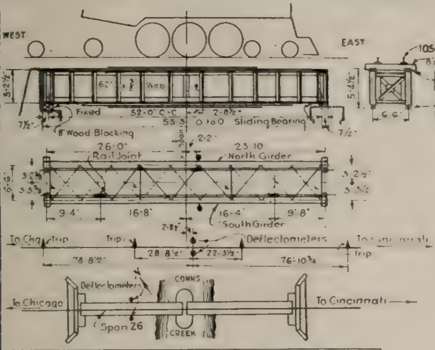
Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D	E U L L (Kips)	Loaded Frequency n	R P S "N"	M P H	Dist "H" (Ft)	Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	D L	L L	Imp	Total
A-399	I	S	E	K5B I	6505	1560	2975	2555	11	P	572	443	664	481	491	6921	72	072	0625	115	162	165	8.75	142	1172
B-132	-	N	·	·	"	"	"	-	-	·	-	481	720	460	491	6930	72	089	0625	142	185	-	950	176	1291
A-402	-	S	E	"	6506	"	-	261.5	8	"	-	483	723	459	558	7869	72	092	0810	113	190	-	954	181	1300
B-135	-	N	·	"	-	-	-	-	-	"	-	.467	700	465	554	7816	72	.088	.0800	1.10	188	-	9.24	174	12.63
					Average- N		Girder					448	670	474			69					165	885		
					-	S	"					456	683	470			69					165	901		
												452	677	472			69					165	894		
A-401	I	S	W	K3Q	6487	1645	2955	1895	6	P	580	.496	7.43	459	421	594	85	092	0483	190	185	165	980	181	1326
B-134	"	N	-	"	-	-	"	-	·	·	-	.445	666	481	421	594	85	077	0483	159	17.3	"	880	152	1197
							Average					470	7.04	470			85					165	929		
A-414	I	S	W	K3J	6458	1600	2740	132.5	6	P	558	423	633	488	388	5468	63	099	0398	249	234	165	835	195	1195
B-147	-	N	·	·	"	·	"	·	-	-	·	385	576	508	387	5457	63	059	0396	149	153	·	760	116	1041
A-394	·	S	W	·	6458	"	-	135.0	5	·	·	437	655	482	395	5569	63	066	0413	160	151	-	865	130	1160
B-127	-	N	-	-	-	"	·	-	-	-	-	390	584	505	394	5564	63	.057	0411	139	146	-	770	112	1047
A-390	-	S	E	K3K	6464	-	·	188.0	4	-	57.7	.411	615	494	504	7116	82	082	.0673	122	199	-	812	162	39
B-123	·	N	"	-	·	-	-	·	·	·	-	.427	640	486	505	7127	82	067	0676	99	157	-	845	133	1143
A-398	-	S	E	-	6464	"	-	183.0	3	-	-	415	621	492	517	7282	82	072	0710	101	174	-	820	143	1128
B-131	-	N	-	-	·	-	-	·	·	-	-	454	680	474	517	7282	82	082	.0710	115	181	-	896	162	1223
A-409	·	S	E	-	6464	"	·	188.0	3	·	·	406	608	502	540	7612	82	065	0772	84	160	-	802	28	1095
B-142	·	N	-	"	-	-	·		·	·	-	443	664	479	540	7614	82	072	0772	95	163	-	875	143	1183
					Average N		Girder					420	629	490			74					165	929		
					·	S	-					418	625	490			74					165	927		
							Both Girders					419	627	490			74					165	928		

Sheet 3 Span 25

Test				Locomotive					Cars		Stat L.L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net. Sec			
No.	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H.	Dist "H" (Ft.)	Oscil (ins)	Stat. Defl H.Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L	L.L	Imp.	Total
A-403	I	S	E	K H	6429	1260	236.0	143.5	5	P	55.9	405	6.06	506	4.43	59.37	7.4	.057	.0413	1.38	14.1	1.65	8.00	1.13	10.78
B-136	..	N	..	..	..	.	..	..	..	..	.	370	5.54	5.25	4.40	58.92	7.4	.057	.0407	1.40	15.4	..	7.31	1.13	10.09
						Average					55.9	388	5.81	5.15			7.4					1.65	7.66		
A-406	I	S	W	K B	6416	1250	222.8	101.0	3	P	54.1	.382	5.72	5.10	3.24	43.45	5.6	.041	.0219	1.87	10.7	1.65	7.55	0.81	10.01
B-139	..	N	..	..	.	.	..	..	..	..	..	354	5.30	5.25	3.28	43.95	5.6	.021	.0225	.93	5.9	..	7.00	0.41	9.06
						Average					54.1	368	5.51	5.17			5.6					1.65	7.27		
A-391	I	S	W	L2 B	6213	1845	364.0	235.0	70	F	56.9	.484	7.25	4.44	3.20	39.35	3.9	.053	.0315	1.68	10.9	1.65	9.56	1.04	12.25
B 124	..	N	.	..	..	..	..	..	..	..	..	484	7.25	4.44	3.18	39.20	3.9	.044	.0310	1.42	9.1	..	9.56	0.87	12.08
A-400	..	S	W	..	6214	.	..	250.5	–	..	..	489	7.32	4.42	3.39	41.66	3.9	.053	.0353	1.50	11.9	..	9.66	1.15	12.46
B-133	..	N	..	..	..	..	..	..	..	..	..	490	7.34	4.42	3.43	42.21	3.9	.041	.0360	1.14	8.4	..	9.68	0.81	12.14
A-411	..	S	W	..	6209	..	..	253.0	–	..	..	503	7.53	4.37	3.49	42.94	3.9	.054	.0374	1.44	10.7	..	9.94	1.06	12.65
B-144	..	N	..	..	..	..	..	..	..	..	..	484	7.25	4.44	3.44	42.35	3.9	.038	.0363	1.05	7.9	..	9.56	0.76	11.97
					Average N	Girder					56.9	486	7.29	4.43			3.9					1.65	9.60		
					..	S	Girder				56.9	.492	7.36	4.41			3.9					1.65	9.73		
					..	Both Girders					56.9	.489	7.32	4.42			3.9					1.65	9.66		
A-408	I	S	W	H7E V	6158	2455	343.1	256.0	-	F	56.3	.520	7.79	4.35	3.49	39.23	7.8	.069	.0494	1.40	13.3	1.65	10.27	1.37	13.29
B-141	..	N	..	..	..	..	..	..	..	..	..	.481	7.20	4.50	3.51	39.41	7.8	.072	.0499	1.44	15.0	..	9.50	1.42	12.57
A-395	..	S	W	..	6153	..	..	247.0	-	..	..	.508	7.60	4.40	3.87	43.56	7.8	.092	.0607	1.51	19.9	..	10.03	2.00	13.68
B-128	..	N	..	..	..	..	..	..	..	.	-	.493	7.38	4.46	3.90	43.89	7.8	.082	.0617	1.33	16.6	..	9.74	1.62	13.01
					Average	N.	Girder				56.3	.487	7.30	4.48			7.8					1.65	9.63		
					..	S.	..				56.3	.514	7.70	4.38			7.8					1.65	10.15		
						Both	Girders				56.3	501	7.50	4.42			7.8					1.65	9.90		

Sheet 4 Span 25

Test				Locomotive					Cars		Stat L.L.Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net. Sec			
No.	Series	Girder	Direc. of Movement	Class	Eng No.	H B at 1 R.P.S.	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist. "P"	Defl. (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H.	Dist "H" (Ft.)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L.	L.L.	Imp.	Total
A-410	I	S	W	H5-LA I	6133	2090	277.8	106.0	–	F	55.0	.420	6.29	4.90	2.85	32.06	6.9	.031	.0279	1.11	7.4	1.65	8.30	0.62	10.57
B-143	..	N	..	..	..	..	..	..	..	..	..	.416	6.24	4.91	2.85	32.06	6.9	.025	.0279	.90	6.0	..	8.22	0.49	10.36
A-389	..	S	W	..	6133	..	..	117.5	21	..	..	.425	6.36	4.88	3.20	36.00	6.9	.026	.0353	.74	6.1	..	8.40	0.51	10.56
B-122	..	N	..	..	..	..	..	..	..	..	..	.408	6.10	4.96	3.20	36.00	6.9	.059	.0353	1.67	11.9	..	8.06	0.96	10.67
					Average		N. Girder				55.0	.412	6.17	4.93			6.9					1.65	8.15		
						..	S. Girder				55.0	.422	6.32	4.89			6.9					1.65	8.34		
						..	Both Girders				55.0	.417	6.25	4.91			6.9					1.65	8.25		
A-405	I	S	W	L2 D	6227	2153	367.0	255.0	–	F	57.0	.476	7.12	4.39	2.33	28.63	3.9	.036	.0191	1.88	7.6	1.65	9.40	0.71	11.76
B-138	..	N	..	..	.	..	..	..	..	..	.	439	6.58	4.55	2.31	28.45	3.9	.033	.0188	1.75	7.5	..	8.67	0.65	10.97
						Average					57.0	.458	6.85	4.46			3.9					1.65	9.05		



Tests A-350 to 387 May 1932
" B- 80 to 120 " "

DESIGN DATA			COMPUTED DEFLECTION (from gross M.of I.)	
Date 1897 Spec. 1893			For 1000 Lbs. per Ft. Trk.	.0505
Material Soft Steel			For 1000 Lbs. at Center	.00157
Loading E-32.4	E.U.L.L.	4870	D.L. Deflection	.0563
Flange Stress	D.L.	1490	D.L. Frequency	14.31
(Tens. N. Sec.)	L.L.	6500		
	Imp.	1050	**COMPUTED FROM TESTS** (using Aver. M. of I. 108890)	
	Total	9040		
Gross M. of I. at Center		119000	Deflec. 1000 Lbs. per Ft. Trk.	.0552
Weight Steel per Ft.		685	Deflec. 1000 Lbs. at Center	.00172
Weight Deck per Ft.		430	Deflec. D.L.	.0615
Total per Ft.		1115	Frequency D.L.	13.70
Total for Span		59400	Average Observed M. of I. / Comp. Gross M. of I.	= .915

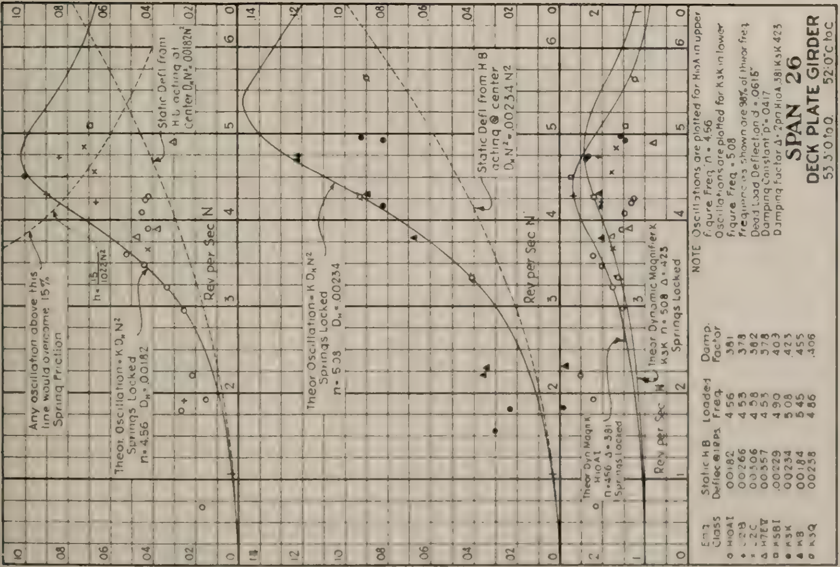
LOCOMOTIVES USED IN TESTS

Class of Engines	KB	KH	K3J K3R K3L	K3Q	K3B (1)					
Engines per class	2	1	4	1	1					
Tests per class	8	2	14	6	4					
Class of Engines	H5-B (II)	H7E (V)	H10-A (I)	L2-B	L2-D					
Engines per class	1	2	1	2	3					
Tests per class	4	6	23	7	5					

SPAN 26

Bridge 387 Chicago Div
West Span Single Track
53'-3 Deck Plate Girder

Fig. 72



Eng Class	Static H B Deflec @ 1 RPS	Loaded Freq	Damp. Factor
○ H10A1	.00182	4.56	.381
+ L2B	.00266	4.53	.378
× L2C	.00306	4.58	.382
△ H7E V	.00357	4.53	.378
□ H5B I	.00229	4.90	.403
● K3K	.00234	5.08	.423
▲ KB	.00184	5.45	.455
◇ K3Q	.00258	4.86	.406

NOTE Oscillations are plotted for H10A in upper figure Freq n = 4.56
Oscillations are plotted for K3K in lower figure Freq = 5.08
Frequencies shown are 98% of theor freq
Dead Load Deflection d = .0615"
Damping Constant 'p' = .0417
Damping factor Δ = 2pn H10A .381 K3K .423

SPAN 26
DECK PLATE GIRDER
53'-3" 0 to 0. 52'-0" C to C

Fig. 73

TABLE XL

BR.No. 387 CHICAGO DIV. 53'-3" D.P.G. 52'-0" c. to c. BEARINGS

Sheet 1 Span 26

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L	L.L	Imp	Total
B-106	1	N	E	K5BI	6506	1560	2975	2748	8	P	458	.467	846	481	450	6355	06	.126	.0464	272	27.0	1.49	11.33	306	1588
A-373	"	S	"	"	"	"	"	"	"	"	"	.403	729	5.13	451	6365	0.6	.080	.0466	173	199	"	978	195	1312
B-114	"	N	W	"	6506	"	"	"	10	"	"	.427	7.74	5.05	5.08	71.70	0.6	.087	0591	147	204	"	10.36	211	1396
A-381	"	S	W	"	"	"	"	"	"	"	"	.415	751	5.07	509	7190	06	.084	.0592	142	20.2	"	10.07	203	1359
				Average 2 Tests North Girder							458	.447	8.10	4.90			0.6					1.49	10.85		
				" 2 " South "							458	409	7.40	510			06					1.49	993		
				" 4 " Both Girders							45.8	428	7.75	5.00			0.6					1.49	10.39		
B-82	1	S	E	K3Q	6487	1645	295.5	209.6	10	P	45.8	.448	811	491	333	3748	1.2	.034	.0265	1.28	7.6	149	10.87	083	1319
A-351	"	N	"	"	"	"	"	"	"	"	"	.417	755	5.06	3.30	3709	"	.042	.0260	161	10.1	"	10.11	102	1262
B-119	"	N	"	"	6487	"	"	"	9	"	"	.437	7.91	4.96	427	6039	"	.095	.0435	218	217	"	1060	217	1426
A-386	"	S	"	"	"	"	"	"	"	"	"	.424	768	5.03	4.27	60.36	"	.085	.0435	195	20.0	"	1029	206	13.84
B-91	"	N	W	"	6487	"	"	"	11	"	"	453	8.20	4.89	5.66	7847	"	.088	.0765	112	19.4	"	11.00	214	14.63
A-358	"	S	"	"	"	"	"	"	"	"	"	.434	7.86	498	5.64	78.24	"	.092	.0760	121	21.2	"	1051	2.25	14.25
				Average 3 Tests North Girder							45.8	.436	7.89	496			1.2					1.49	1057		
				" 3 " South "							458	435	788	497			1.2					1.49	10.56		
				" 6 " Both Girders							45.8	.436	7.88	4.96			1.2					1.49	1056		
B-83	1	S	W	K3J	6458	1605	274.0	209.6	5	P	48.3	.392	7.10	5.13	1.54	2179	3.7	.023	.0056	410	5.9	1.49	9.51	.56	11.56
A-352	"	N	"	"	"	"	"	"	"	"	"	.358	6.48	5.34	156	2193	"	030	.0057	5.25	84	"	8.69	.73	10.91
B-81	"	S	"	K3K	6464	"	"	"	6	"	"	.390	7.07	514	1.82	25.60	"	.019	0078	2.44	49	"	946	.46	1141
A-350	"	N	"	"	"	"	"	"	"	"	"	361	6.54	5.31	182	25.64	"	.023	0078	2.95	64	"	8.76	56	10.81
B-118	"	N	"	"	6464	"	"	"	7	"	"	378	6.85	521	4.16	588	"	.044	.0405	1.09	116	"	9.18	106	1173
A-385	"	S	"	"	"	"	"	"	"	"	"	.378	6.85	5.21	416	58.85	"	.082	.0405	202	21.7	"	9.18	199	1266

Sheet 2 Span 26

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L	L.L	Imp.	Total
B-116	1	N	E	K3K	6467	1605	274.0	2096	3	P	48.3	.423	7.66	4.96	4.70	6640	3.7	.122	.0518	236	28.8	1.49	10.26	3.56	15.31
A-383	"	S	"	"	"	"	"	"	"	"	"	.353	6.39	5.36	476	6715	"	.073	.0531	1.37	20.7	"	8.57	1.78	1184
B-94	"	N	"	"	6467	"	"	"	"	"	"	.386	6.99	5.16	476	67.15	"	.122	.0531	2.30	31.6	1.49	9.37	2.96	13.82
A-361	"	S	"	"	"	"	"	"	"	"	"	.383	6.94	5.18	4.75	67.10	"	.084	.0530	1.58	21.9	"	9.28	2.03	1280
B-120	"	N	W	K3J	6458	"	"	"	6	"	"	.379	6.86	5.20	4.93	69.57	"	.058	.0570	1.02	15.3	"	9.20	1.41	12.10
A-387	"	S	"	"	"	"	"	"	"	"	"	.404	7.31	5.06	4.93	69.57	"	.082	.0570	1.44	20.3	"	9.80	1.99	13.28
B-105	"	N	"	K3L	6472	"	"	"	"	"	"	.392	7.10	5.13	496	69.93	"	.050	.0578	.87	12.7	"	9.51	1.21	12.21
A-372	"	S	"	"	"	"	"	"	"	"	"	.392	7.10	5.13	4.97	70.12	"	.092	0580	1.59	234	"	9.51	2.23	13.23
				Average 7 Tests North Girder							48.3	.382	6.93	5.19			3.7					1.49	9.27		
				" 7 " South "							48.3	.385	6.97	5.17			3.7					1.49	9.34		
				" 14 " Both Girders							483	.383	6.95	5.18			3.7					1.49	9.30		
B-107	1	N	W	KH	6429	1260	236.0	162.0	5	P	48.0	.387	7.01	5.55	4.00	53.58	4.4	.042	.0294	143	10.9	1.49	9.39	1.02	11.90
A-374	"	S	"	"	"	"	"	"	"	"	"	.389	7.05	553	3.98	53.31	"	.058	.0291	1.99	14.9	"	9.43	1.40	12.32
				Average 2 Tests Both Girders							48.0	.388	7.03	5.54			4.4					1.49	9.41		
B-90	1	N	W	K-B	6412	1250	222.8	151.2	3	P	47.6	.353	6.39	5.57	2.20	29.54	40	.028	.0089	3.14	7.9	1.49	8.56	.68	10.73
A-357	"	S	"	"	"	"	"	"	"	"	"	.382	6.92	5.34	2.20	29.54	"	.023	.0089	2.58	6.0	"	927	56	11.32
B-113	"	N	"	"	6416	"	"	"	3	"	"	.348	6.30	560	229	30.65	"	.010	.0097	1.03	2.9	"	845	25	1019
A-380	"	S	"	"	"	"	"	"	"	"	"	.335	6.07	5.69	2.28	30.56	"	.027	.0096	2.81	81	"	8.13	.66	1028
B-87	"	N	E	"	6416	"	"	"	3	"	"	.315	5.71	5.84	378	5065	"	.023	.0264	.87	7.3	"	7.65	.56	9.70
A-354	"	S	"	"	"	"	"	"	"	"	"	.357	6.47	5.55	3.79	5085	"	.053	.0265	2.00	14.8	"	866	1.28	1143

Sheet 3 Span 26

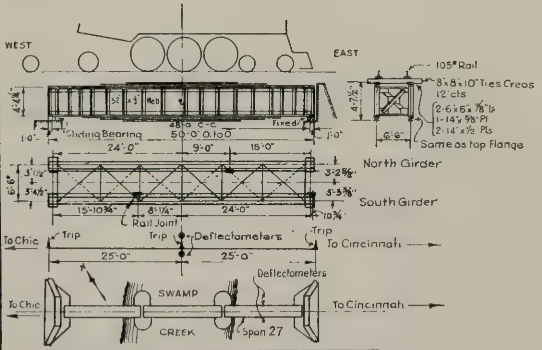
Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		EULL (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact γ	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) 'D'			RPS 'N'	MPH	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
B-111	1	N	E	KB	6412	1250	222 8	151 2	3	P	47.6	.368	6 67	5 47	4 30	57.62	4 0	070	0340	2 06	19.0	149	892	1.69	1210
A-378	·	S	·	..		·	-	..	..	-	·	374	6 78	5 43	4 29	5738	-	.066	0340	1 94	176	..	907	160	12.16
				Average	4 Tests	North Girder					47.6	346	627	5.61			40					149	840		
				-	4 -	South -					47.6	362	656	5 51			40					149	879		
				.	8 ..	Both Girders					47.6	.354	6 41	5.56			40					149	860		
B-85	1	N	E	L2D	6227	2155	3670	309.6	54	F	48 4	409	740	497	366	45 11	0.2	.071	0411	173	17.4	149	992	1.72	13.13
A-353	..	S	..	-	..	·	·	..	·	·	-	453	820	475	3.66	4506	..	.066	.0411	160	14.6	..	11 00	160	1409
B-117	·	N	W	·	6226	-	·	·	60	-	·	.481	871	463	455	5604	..	085	0635	134	177	..	11 67	206	1522
B-384	..	S	-	-	..	..	·	·	-	·	·	.476	862	4.65	455	55.98	·	.112	.0635	176	235	..	11 54	272	15.75
B-84	..	N	E	-	6228	-	-	..	·	..		.541	980	439	484	59.63	·	120	0720	1.67	222	-	13 13	292	1754
				Average	3 Tests	North Girder					484	477	864	465			02					149	11 68		
				..	2 ..	South	..				484	.465	841	4.70			02					149	11 29		
				..	5 ..	Both Girders					48.4	.471	855	467			02					149	11 43		
B-80	1	S	W	L2B	6213	1845	364.0	283 8	71	F	48.5	.454	8.22	466	191	2344	0.3	.037	.0097	382	82	149	11.01	.90	1340
B-109	·	N	E	..	6213	..	..	·	38	-	..	.462	8 37	463	423	5200	·	097	.0478	203	210	-	11.21	236	15.06
A-376	·	S	..	..	..	·	·	·	-	·	·	.405	7.33	490	4 19	5.50	..	.079	0469	168	195	-	9.83	192	1324
B-108	·	N	..	..	6210	..	-	·	39	-	-	518	938	440	427	5260	·	.131	0488	268	25.3	..	12.56	3.18	1723
A-375	..	S	..	..	..	..	..	..	-	..	..	.465	842	462	428	5268	..	110	.0489	225	237	..	[illegible]28	268	1545
B-104	..	N	W	..	6210	..	..	..	..	..	-	.467	8.46	461	472	5804	-	122	0595	205	261	·	11.32	296	15.77
A-371	-	S	-	·	..	·	-	..	..	..	·	.474	858	4.58	471	5791	..	.115	.0593	1.94	243	..	11 50	279	15.78
				Average	3 Tests	North Girder					485	482	874	454			03					149	11 70		
				..	4 ·	South	·				485	450	814	468			03					149	1091		
				..	7 ..	Both Girders					485	463	8.39	462			03					149	1130		

Sheet 4 Span 26

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		EULL (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact γ	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D			RPS 'N'	MPH	Dist 'H' (Ft)	Oscil (ins)				DL	LL	Imp	Total
B-88	1	N	E	H7E V	6153	2455	3431	2760	34	F	454	409	740	479	380	4272	18	055	0517	106	13.5	149	991	1.34	12.74
A-355	..	S	..	·	·	..	..	..	·	..	..	493	893	441	379	4261	·	092	05 5	179	187	·	1195	224	1468
B-110	·	N		-	6156	-	-	·	47		·	494	894	441	390	4382	..	073	0544	134	148	-	1197	177	1523
A-377	·	S	·	..	·	..	..		·	..		.427	774	470	390	4382	-	050	.0544	92	117	-	1036	121	1306
B-89	·	N	W	-	6156	·			10	·		403	730	482	490	5514	..	.055	0860	65	137		978	134	1261
A-356		S	-		..	·	·		-	·		440	797	464	490	5514		059	.0860	69	134		1067	143	1359
				Average	3 Tests	North Girder					454	435	788	466			18					149	1055		
				..	3	- South Girder					454	453	821	458			18					149	1098		
				..	6	Both Girders					454	444	805	462			18					149	1077		
B-112	1	N	W	H5-0II	6706	2092	2757	1620	5	F	441	.406	735	499	292	32.84	09	031	0259	120	76	149	985	75	1209
A-379	·	S	..	..	·	·	·	·	..	..	-	.410	742	496	291	3276	·	037	.0258	143	90	..	995	89	1233
B-115		N	E	-	6706	·	·	..	4			422	765	491	387	4346	-	069	0455	152	163	·	1024	167	1340
A-382		S	·		·	·	·	·	·	·	·	421	763	491	378	4254	·	.069	.0435	158	164	·	1021	168	1338
				Average	2 Tests	North Girder					441	414	750	495			09					149	1003		
					2	South					441	415	753	494			09					149	1006		
				..	4 ·	Both Girders					441	415	752	494			09					149	1004		
B-93	1	N	E	H10 A I	13	1270	3350	2760	None		457	383	694	500	068	767	22	015	0008	187	39	149	929	36	1114
A-360		S		..			·	·				423	765	479	068	766	·	[illegible]	0008	[illegible]	40	-	1026	41	[illegible]
B-92	·	N	·	·	13	..	·	·	·		·	459	831	[illegible]	181	2033	-	027	0060	[illegible]	59	-	1113	66	[illegible]
A-359	-	S	·	·	·	·	·	·	·		·	423	766	479	180	[illegible]		[illegible]	[illegible]	[illegible]	45		1026	46	[illegible]
B-86		N	·		13			·			·	391	708	496	193	[illegible]		[illegible]	[illegible]	[illegible]	38		948	36	[illegible]
B-96	·	N		·	3							433	[illegible]	[illegible]	220	2468		014	[illegible]	[illegible]	[illegible]		[illegible]	34	[illegible]
A-363		S		·								[illegible]	785	[illegible]	[illegible]	[illegible]		[illegible]	0088	[illegible]	[illegible]		[illegible]	53	[illegible]

Sheet 5 Span 26

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "p"	Defl. (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat. Defl H Blow $D_h N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L	L L	Imp	Total
B-95	1	N	E	H10A I	13	1270	335.0	276.0	No	ne	457	.469	8.49	4.58	2.97	33.37	2.2	.025	.0161	1.55	5.3	1.49	11.38	.60	13.47
A-362	"	S	"	"	"	"	"	"	"	"	"	.456	8.26	4.64	2.97	33.40	"	.022	.0161	1.37	4.8	"	11.06	.53	13.08
B-97	"	N	"	"	13	"	"	"	"	"	"	.468	8.48	4.59	3.22	36.20	"	.028	.0189	1.48	6.0	"	11.35	.68	13.52
A-364	"	S	"	"	"	"	"	"	"	"	"	.453	8.20	4.65	3.22	36.20	"	.033	.0189	1.75	7.3	"	11.22	.82	13.53
B-98	"	N	"	"	13	"	"	"	"	"	"	.482	8.74	4.53	3.48	39.15	"	.033	.0221	1.49	6.9	"	11.70	.81	14.00
A-365	"	S	"	"	"	"	"	"	"	"	"	.439	7.95	4.71	3.47	39.00	"	.044	.0220	2.00	10.0	"	10.65	1.07	13.21
B-99	"	N	"	"	13	"	"	"	"	"	"	.473	8.56	4.56	3.59	40.35	"	.052	.0235	2.21	11.0	"	11.47	1.26	14.22
A-366	"	S	"	"	"	"	"	"	"	"	"	.442	8.01	4.70	3.56	40.06	"	.037	.0231	1.60	8.4	"	10.72	.90	13.11
B-102	"	N	"	"	13	"	"	"	"	"	"	.432	7.83	4.75	3.91	43.98	"	.030	.0279	1.08	6.9	"	10.49	.72	12.60
A-369	"	S	"	"	"	"	"	"	"	"	"	.486	8.80	4.51	3.90	43.82	"	.042	.0277	1.52	8.6	"	11.80	1.01	14.30
B-100	"	N	"	"	13	"	"	"	"	"	"	.440	7.97	4.71	4.09	46.01	"	.045	.0305	1.48	10.2	"	10.68	1.09	13.26
A-367	"	S	"	"	"	"	"	"	"	"	"	.468	8.48	4.55	4.08	45.83	"	.041	.0304	1.35	8.8	"	11.35	1.00	14.84
B-101	"	N	"	"	13	"	"	"	"	"	"	.443	8.03	4.70	4.25	47.74	"	.043	.0329	1.31	9.7	"	10.74	1.04	13.27
A-368	"	S	"	"	"	"	"	"	"	"	"	.482	8.73	4.53	4.19	47.09	"	.039	.0321	1.21	8.1	"	11.70	95	14.14
B-103	"	N	"	"	13	"	"	"	9	F	"	488	8.34	4.50	4.23	47.59	"	.030	.0326	.92	6.2	"	11.84	.73	14.06
A-370	"	S	"	"	"	"	"	"	"	"	"	.476	8.62	4.55	4.27	47.98	"	.042	.0333	1.26	8.8	"	11.55	1.02	13.06
				Average	12 Tests	North Girder					45.7	447	8.05	418			2.2					1.49	10.85		
				"	11	"	South	"			45.7	.453	8.20	465			2.2					1.49	11.00		
				"	23	"	Both Girders				45.7	.450	8.12	466			2.2					1.49	10.92		



1st Series Tests A-180 to 204 September 1931

2nd Series " A 256 to 287 October 1931

2nd Series " B 1 to 35 " "

First Series - Tests on South Girder

Second " - Tests on Both Girders

DESIGN DATA

Date 1913 Spec. 1910
Material O H Steel
Loading E- 60 E.U.L.L. 9260
Flange Stress D.L. 1320
(Tens.N.Sec.) L.L. 8500
Imp. 7350
Total 17170
Gross M.of I.at Center 124010
Weight Steel per Ft. 945
Weight Deck per Ft. 490
Total per Ft. 1435
Total for Span 71800

COMPUTED DEFLECTION
(from gross M.of I.)

For 1000 Lbs.per Ft.Trk. .03505
For 1000 Lbs.at Center .00117
D.L. Deflection .05031
D.L. Frequency 14.90

COMPUTED FROM TESTS
(using Aver.M.of I. 110620)

Deflec.1000 Lbs.per Ft.Trk. .0393
Deflec.1000 Lbs.at Center .00131
Deflec.D.L. .0564
Frequency D.L. 14.05

$$\frac{\text{Average Observed M. of I.}}{\text{Comp. Gross M. of I.}} = .892$$

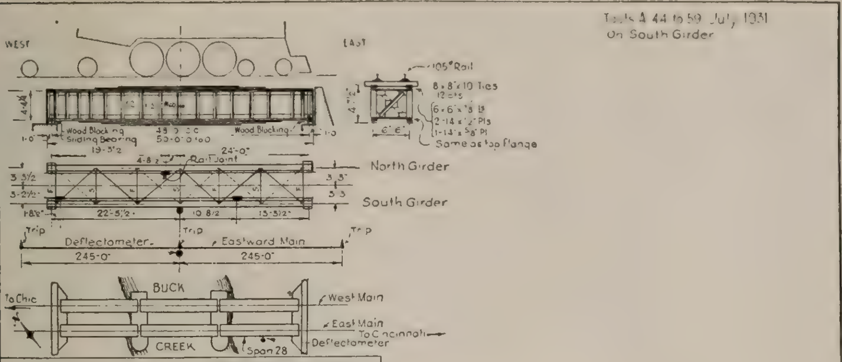
LOCOMOTIVES USED IN TESTS

Class of Engines	K	Ko	K5J K5L	K5Q	K5B (I)	J1D				
Engines per class	1	1	2	2	3	1				
Tests per class	8	9	5	11	12	2				
Class of Engines	H6L (I)	H5-O (II)	H7E (I)	H7E (V)	H10A (I)	L2B	L2D			
Engines per class	1	3	1		4	3	5			
Tests per class	2	12	1	2	7	7	4			

SPAN 27

Bridge 427 Chicago Div
East Span- Single Track
50'-0" Deck Plate Girder

Fig. 74



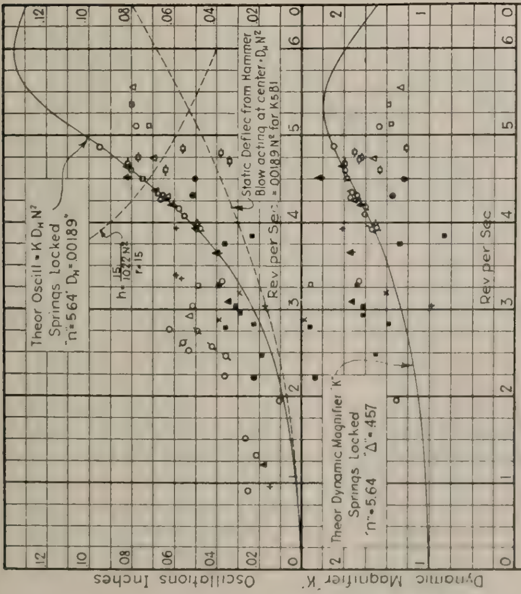
DESIGN DATA		COMPUTED DEFLECTION (from gross M.of I.)	
Date 1916 Spec. 1910		For 1000 Lbs.per Ft.Trk.	.03505
Material OH Steel		For 1000 Lbs.at Center	.00117
Loading E-60	E.U.L.L. 9260	D.L. Deflection	.0489
Flange Stress	D.L. 1290	D.L. Frequency	15.12
(Tens.N.Sec.)	L.L 8500		
	Imp. 7350	**COMPUTED FROM TESTS** (using Aver.M.of I. 110620)	
	Total 17140		
Gross M.of I.at Center	124010	Deflec.1000 Lbs.per Ft.Trk.	.0393
Weight Steel per Ft.	945	Deflec.1000 Lbs.at Center	.00131
Weight Deck per Ft.	450	Deflec.D.L.	.0548
Total per Ft.	1395	Frequency D.L.	14.23
Total for Span	69800	Average Observed M.of I. / Comp.Gross M.of I.	= .892

LOCOMOTIVES USED IN TESTS

Class of Engines	K	K5K	K5B I							
Engines per class	1	1	3							
Tests per class	2	1	6							
Class of Engines	H10B I	L2B	L2D							
Engines per class	1	1	1							
Tests per class	2	1	1							

SPAN 28
Bridge 446 Chicago Div
East Span-East Main
50'-0" Deck Plate Girder

Fig. 75



Eng Class	Static H B Defl @ 1 RPS "D_H"	Loaded Frequency "n"	Damping Factor 'Δ'
○ K5B I	.00189"	5.64	.457
J1D	.00208"	5.40	.437
K3Q	.00200"	5.58	.452
△ K5J	.00195"	5.79	.469
□ K O	.00148"	5.97	.484
K	.00154"	6.16	.498
● L2D	.00250"	5.55	.450
▲ L2B	.00217"	5.56	.451
+ H10A I	.00188"	5.48	.444
× H7E	.00296"	5.49	.445
■ H50 II	.00252"	5.54	.449
◆ H10B I	.00136"	5.48	.444

NOTE: Oscillations are plotted for K5B I Eng. Frequency = 5.64
Frequencies shown are 96.5% of theoretical
D.L. Defl Span 27 = .0564"
D.L " Span 28 = .0548"
Damping Constant "p" = .0405
Δ = 2pn-Span 27 = .457

SPANS 27 & 28
DECK PLATE GIRDER
50'-0" O.to O. 48'-0" C.to C.

Fig. 76

TABLE XLI

BRIDGE No 427 CHICAGO DIV. 48'-0" C to C. 50'-0" O to O D.P.G.

Sheet 1 Span 27

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L.L Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1RPS	Weight (Kips)		No	Kind	at Dist "P"	Defl. (ins) "D"			R.P.S "N"	M.P.H.	Dist "H" (Ft)	Oscil (ins)				DL	L.L.	Imp	Total
							Eng	Tender																	
B-34	2	S	E	J1 D	6603	1690	353.0	303.0	4	P	44.5	.316	8.05	5.60	2.59	36.52	1.3	.061	.0140	4.35	19.3	1.32	7.42	1.43	1017
A-286	2	"	"	"	"	"	"	"	"	"	44.5	.324	8.25	5.54	2.61	36.83	1.3	.063	0142	4.43	19.4	"	760	1.47	10.39
					Average						44.5	.320	8.15	5.57			1.3					1.32	7.51		
A-204	1	S	E	K5B1	6513	1560	297.5	274.8	9	P	43.5	.289	735	5.82	2.24	31.64	0.3	.036	.0095	3.79	12.5	1.32	678	0.85	8.95
A-198	1	"	W	"	6505	"	"	"	11	"	43.5	.293	7.45	579	2.52	35.57	0.3	.053	.0120	4.41	18.1	"	6.88	1.24	9.44
B-7	2	N	E	"	6506	"	"	"	3	"	43.5	.292	7.43	5.80	2.76	38.90	0.3	.062	.0144	4.30	21.2	"	6.85	1.45	9.62
A-259	2	S	"	"	6506	"	"	"	3	"	43.5	.291	740	5.81	2.76	38.91	0.3	.062	.0144	4.30	21.3	"	6.83	1.45	9.60
A-182	1	"	W	"	6513	"	"	"	11	"	43.5	.292	7.43	5.80	3.04	42.95	0.3	.051	.0175	2.91	17.5	"	6.85	1.20	9.37
B-1	2	N	"	"	6513	"	"	"	11	"	43.5	.296	7.54	5.77	3.32	46.90	0.3	.038	.0209	1.82	12.8	"	6.95	0.89	9.16
B-30	2	S	"	"	6513	"	"	"	10	"	43.5	.292	7.43	5.80	4.08	57.60	0.3	.057	.0315	1.81	19.5	"	6.85	1.34	9.51
A-282	2	N	"	"	6513	"	"	"	10	"	43.5	.294	7.48	5.79	4.08	57.60	0.3	.053	.0315	1.68	18.0	"	6.90	1.24	9.46
A-274	2	S	E	"	6513	"	"	"	8	"	43.5	.292	7.43	5.80	4.23	59.65	0.3	.068	.0339	2.01	23.3	"	6.85	1.60	9.77
B-22	2	N	"	"	6513	"	"	"	8	"	43.5	.287	730	5.85	4.30	60.55	0.3	.065	.0350	1.86	22.6	"	6.74	1.52	9.58
B-14	2	N	W	"	6506	"	"	"	3	"	43.5	.292	7.43	5.80	4.60	64.90	0.3	.078	.0400	1.95	26.7	"	6.85	1.83	10.00
A-266	2	S	W	"	6506	"	"	"	3	"	43.5	.285	7.25	5.86	4.61	65.05	0.3	.082	.0403	2.04	28.8	"	669	1.93	9.94
				Average 12 Tests							43.5	.291	7.40	5.81			0.3					1.32	6.83		
A-192	1	S	E	K3L	6472	1600	274.0	209.6	5	P	42.8	.266	6.77	6.00	2.92	41.15	0.2	.054	.0167	3.24	20.3	1.32	6.25	1.27	8.84
B-33	2	"	W	K3J	6458	"	"	"	7	"	"	260	6.62	6.06	4.25	59.95	"	.066	.0352	1.88	25.4	"	6.10	1.55	8.97
A-285	2	N	"	"	6458	"	"	"	7	"	"	.273	6.95	5.93	4.25	60.05	"	.065	.0352	1.85	23.8	"	6.41	1.53	9.26
B-6	2	"	"	"	6458	"	"	"	6	"	"	.275	7.00	5.91	5.54	78.10	"	.074	.0600	1.23	26.9	"	6.45	1.74	9.56
A-258	2	S	"	"	6458	"	"	"	6	"	"	.268	6.82	5.98	5.54	78.10	"	.085	.0600	1.42	31.8	"	6.30	2.00	9.62
				Average 5 Tests							42.8	.269	6.85	5.97			0.2					1.32	6.31		

Sheet 2 Span 27

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H.Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec			
No	Series			Class	Eng No.	H. B. at 1RPS	Weight (Kips)		No	Kind	at Dist "P"	Defl (ins) D			R.P.S "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)				D.L.	L.L.	Imp.	Total
							Eng	Tender																	
A-185	1	S	W	K3Q	6487	1645	295.5	209.6	7	P	43.2	.276	7.03	5.90	2.47	34.89	0.6	.038	.0122	3.11	13.8	1.32	6.49	0.90	8.71
A-202	1	"	"	"	6488	"	"	"	7	"	43.2	.298	7.59	5.71	2.56	36.09	0.6	.045	.0132	3.41	15.1		7.00	1.06	9.38
B-35	2	"	E	"	6487	"	"	"	8	"	43.2	.296	7.54	5.72	2.75	38.87	0.6	.051	.0152	3.35	17.2		6.95	1.19	9.46
A-287	2	"	"	"	6487	"	"	"	8	"	43.2	.296	7.54	5.72	2.75	38.92	0.6	.053	.0152	3.49	18.2		6.95	1.26	9.53
B-8	2	N	"	"	6487	"	"	"	8	"	43.2	.314	7.99	5.59	3.93	55.45	0.6	.048	.0309	1.55	15.2		7.37	1.11	9.80
A-260	2	S	"	"	6487	"	"	"	8	"	43.2	.274	6.97	5.91	3.95	55.75	0.6	.053	.0312	1.70	19.3		6.44	1.24	9.00
A-268	2	"	W	"	6487	"	"	"	11	"	43.2	.294	7.48	5.74	3.93	55.50	0.6	.047	.0309	1.52	15.8		6.90	1.09	9.31
B-16	2	N	"	"	6487	"	"	"	11	"	43.2	.298	7.59	5.71	3.93	55.55	0.6	.056	.0309	1.81	19.0		7.00	1.33	9.65
A-187	1	S	E	"	6488	"	"	"	10	"	43.2	.290	7.38	5.77	4.17	58.90	0.6	.061	.0349	1.75	21.0		6.81	1.43	9.56
B-20	2	N	W	"	6488	"	"	"	7	"	43.2	.296	7.54	5.72	4.30	60.60	0.6	.067	.0370	1.81	22.6		6.95	1.57	9.84
A-272	2	S	"	"	6488	"	"	"	7	"	43.2	.294	7.49	5.74	4.30	60.65	0.6	.070	0370	1.89	23.8		6.90	1.64	9.86
					Average						43.2	.293	7.45	5.75			0.6					1.32	6.88		
A-188	1	S	E	KO	6451	1200	246.0	163.2	5	P	41.1	.244	6.20	6.20	3.27	43.77	-0.5	.038	.0159	2.39	15.6	1.32	5.78	0.90	8.00
B-24	2	N	"	"	6451	"	"	"	6	"	41.1	.243	6.18	6.20	4.33	58.00	-0.5	.050	.0278	1.80	20.6	"	5.70	1.17	8.19
A-276	2	S	"	"	6451	"	"	"	6	"	41.1	.237	6.03	6.27	4.31	57.70	-0.5	.055	.0275	2.00	23.2	"	5.57	1.29	8.18
B-9	2	N	"	"	6451	"	"	"	6	"	41.1	.244	6.20	6.20	4.50	60.35	-0.5	.059	.0300	1.97	24.2	"	5.78	1.40	8.50
A-261	2	S	"	"	6451	"	"	"	6	"	41.1	.252	6.41	6.11	4.50	60.40	-0.5	.059	.0300	1.97	23.4	"	5.92	1.39	8.36
B-25	2	"	W	"	6451	"	"	"	4	"	41.1	.250	6.36	6.13	5.09	68.18	-0.5	.061	.0385	1.58	24.4	"	5.86	1.43	8.61
A-277	2	N	"	"	6451	"	"	"	4	"	41.1	.249	6.34	6.14	5.12	68.59	-0.5	.052	.0389	1.34	20.9	"	5.85	1.22	8.39
A-265	2	S	"	"	6451	"	"	"	4	"	41.1	.251	6.39	6.12	5.33	71.32	-0.5	.064	.0422	1.52	25.5	"	5.89	1.50	8.71
B-13	2	N	"	"	6451	"	"	"	4	"	41.1	.250	6.36	6.13	5.36	71.77	-0.5	.062	.0425	1.46	24.8	"	5.86	1.45	8.63
					Average						41.1	248	6.31	6.15			-0.5					1.32	5.82		

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Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D	E U L L (Kips)	Loaded Frequency n	R P S N	M P H	Dist H (Ft)	Oscil (ins)	Stat Defl H Blow Dh Nt at Center	Dynamic Magnifier K	Impact	DL	LL	Imp	Total
A-200	1	S	E	K	6401	1250	2228	512	3	P	418	238	606	638	397	5315	02	040	0244	164	168	132	559	094	785
B-18	2	N	"	"		"	"	"	"		41 8	259	660	617	459	6142	02	053	0325	163	205	"	608	125	865
A-270	2	S		"		"	"	"	"	"	41 8	.223	567	655	462	6187	02	051	0330	155	229	"	524	120	776
B-31	2	"	"	"		"			"		41 8	242	616	634	469	6278	02	063	0339	186	26.0	"	568	148	848
A-283	2	N	"	"	"	"	"	"	"	"	41.8	241	614	635	465	6232	02	071	.0334	212	295	"	566	167	8.65
A-184	1	S	"	"	"	"	"	"	"	"	41 8	241	6.14	635	475	6363	02	.063	.0348	181	262	"	566	148	846
B-4	2	N	"	"	"	"	"	"	"	"	41 8	.241	6 14	635	485	6500	02	043	0363	118	17.8	"	566	1.01	7.99
A-256	2	S	"	"	"	"	"	"	"	"	418	.242	6 16	634	484	6490	02	.049	.0361	1.36	202	"	568	115	8 15
						Average					418	.241	6 14	635			0.2					132	5.66		
A-193	1	S	E	L2D	6229	2153	3670	310.1	60	F	44.8	.320	8.15	5.72	2.22	2734	-1 4	029	.0124	234	9.1	132	751	068	9.51
B-32	2	"	W	"	6227	"	"	"	57	"	44 8	320	8.15	5.72	3.31	40.73	-1 4	053	.0275	193	16.6	"	751	1.25	10.08
A-284	2	N	"	"	6227	"	"	"	57	"	44 8	.318	8.10	5.74	3.28	4039	-1 4	048	.0270	176	15.1	"	746	113	9 91
A-191	1	S	E		6228	"	"	"	42	"	44 8	318	8 10	5.74	450	5542	-1.4	.066	.0508	130	20.8	"	7.46	155	10 33
						Average					44 8	.319	8 12	5.73			-1 4					1.32	7.49		
A-201	1	S	W	L2B	6211	1844	364.0	2923	74	F	44 8	.317	8 06	577	3.07	3776	-1.4	.039	.0205	190	12 3	1 32	7.44	092	9.68
B-23	2	N	"	"	6213	"			58	"	44 8	339	8.63	5.60	4 21	51 85	-1 4	069	.0385	179	20 4	"	795	162	10 89
A-275	2	S	"	"	6213	"			58	"	44.8	.284	724	6.04	4 21	51.85	-1 4	.071	.0385	184	25.0	"	667	167	9.66
B-5	2	N	"	"	6211	"			63	"	44 8	.318	8 10	5 76	4 35	53.50	-1 4	.076	.0411	185	23.9	"	746	1 78	10.56
A-257	2	S	"	"	6211	"			63	"	44.8	.319	8 12	575	4 35	5350	-1.4	.081	.0411	197	254	"	749	190	10 71
B-11	2	N	E	"	6214	"			49	"	44 8	.345	8.78	556	464	57.05	-1.4	.091	.0469	194	264	"	810	2 14	11.56
A-263	2	S	"	"	6214	"			49	"	44 8	.319	8.12	575	464	57.00	-1.4	.096	0469	2 05	30.1	"	749	226	11 07
						Average					44 8	.320	8.15	5.74			-1.4					1.32	751		

Sheet 4 Span 27

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist P	Defl (ins) D	E.U.L.L. (Kips)	Loaded Frequency n	R.P.S. N	M.P.H.	Dist H (Ft)	Oscil (ins)	Stat Defl H Blow Dh Nt at Center	Dynamic Magnifier K	Impact	DL	LL	Imp	Total
A-189	1	S	E	H10A I	29	1650	3350	2760	77	F	44 2	.321	8.17	5.65	095	1068	1 9	.015	.0018	8.33	47	1.32	754	0 35	9.21
A-190	1	"	"	"	20	"	"	"	80	"	44 2	.325	8 27	5.63	3 03	34 06	"	017	0173	098	52	"	763	0.40	9 35
A-201	1	"	W	"	29	"	"	"	74	"	44 2	.320	8 15	5.66	3 36	37.76	"	.057	.0213	2 68	17.8	"	751	1 34	10 17
B-26	2	"	"	"	13	"	"	"	66	"	44 2	324	8.25	5 64	3 38	3796	"	.061	.0215	2 84	18 8	"	760	1 43	10 35
A-278	2	N	"	"	13	"	"	"	66	"	44 2	.324	8 25	5 64	3 37	3784	"	.057	.0214	2 66	17.6	"	760	1 34	10 26
B-10	2	"	E	"	15	"	"	"	85	"	44 2	.322	8 20	5 65	3 91	4395	"	.057	.0289	1 97	177	"	756	1 34	10 22
A-262	2	S	"	"	15	"	"	"	85	"	44 2	.320	8 15	5 66	3 95	44 40	"	.061	.0294	2.07	191	"	751	144	10 27
						Average					44 2	.322	8 20	5 65			1 9					132	756		
A-271	2	S	W	H7E V	6156	2455	343.1	2760	66	F	43 9	.321	8.17	5.65	2.88	3244	2.3	.062	.0246	2 52	193	132	754	1 45	10 31
B-19	2	N	"	"	6156	"	"	"	66	"	43 9	.320	8.15	5 66	2 88	32.31	2 3	.060	0246	2 44	18 8		751	1 41	10 24
						Average					43 9	.320	8.15	5 66			2 3					132	7.51		
A-195	1	S	W	H7E I	6163	2455	3280	1836	42	F	44 5	.302	769	566	3 18	3576	-2 9	.045	.0300	1 50	149	1 32	709	1.06	9 47
A-183	1	S	E	H5L I	6002	2092	2757	1505	[illegible]	F	42 2	.291	741	568	3.06	3436	-1 0	.051	0237	2 15	175	1 32	6 84	1.20	9 36
A-181	1	"	W	"	6002	"	"	"	5	"	42 2	.280	713	5 77	3 40	38 18	-1 0	.046	.0292	1 57	164	"	6 58	1 08	8 98
						Average					42.2	.286	729	5 72			1 0					1 32	6 71		
B-3	2	N	E	H 50 II	6713	2092	2753	1620	5	F	42 2	.304	7.74	5 61	2 48	27.92	-1 0	.026	.0156	1.67	85	1 32	7 14	0.61	9 07
B-29	2	S	"		6706	"	"	"	12	"	42 2	288	7 34	5 74	2 78	31 25	-1 0	.039	.0196	1 99	13.5	"	6 76	0.91	8 99
A-281	2	N	"		6706	"	"	"	12	"	42 2	.301	7 66	5.64	2 80	31 51	-1 0	.056	0198	2 82	186	"	7 06	1 31	9 69
B-17	2	"	"		6709	"	"	"	15	"	42 2	292	7 43	5 71	2 82	31.68	-1 0	.029	.0201	1 44	99	"	6 85	0 68	8 85
A-269	2	S	"		6709	"	"	"	15	"	42 2	284	7 23	5 78	2 84	31 92	-1 0	.031	0204	1 62	109	"	6 67	0 73	8 72
A-199	1	"			6706	"			12	"	42.2	276	7 03	5 85	2 94	33 00	-1 0	.039	.0219	1 78	141	"	6 48	0 91	8 71

Sheet 5 Span 27

Test				Locomotive					Cars		S'at L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H.	Dist "H" (Ft.)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D L	L.L	Imp	Total
A197	1	S	W	H50 II	6706	2092	275.3	162.0	10	F	42.2	280	7.13	5.81	3.03	34.02	-1.0	.041	.0232	1.77	14.6	1.32	6.58	0.96	8.86
B-15	2	N	"	"	6709	"	"	"	19	"	42.2	.280	7.13	5.81	3.75	42.14	-1.0	.046	.0355	1.30	16.4	"	6.58	1.08	8.98
A-267	2	S	"	"	6709	"	"	"	19	"	42.2	.289	7.35	5.73	3.74	42.09	-1.0	.050	.0354	1.41	17.3	"	6.79	1.17	9.28
B-2	2	N	"	"	6713	"	"	"	6	"	42.2	.302	7.69	5.63	3.84	43.21	-1.0	.031	.0373	0.83	10.3	"	7.10	0.73	9.15
A-279	2	N	"	"	6706	"	"	"	8	"	42.2	.293	7.45	5.70	4.24	47.62	-1.0	.082	.0455	1.80	28.0	"	6.88	1.93	10.13
B-27	2	S	"	"	6706	"	"	"	8	"	42.2	.293	7.45	5.70	4.28	48.10	-1.0	.086	.0464	1.85	29.4	"	6.88	2.02	10.22
						Average					42.2	290	7.38	5.72								1.32	6.81		

NOTE:- Tender weights are for full tender. Frequencies shown are theoretical frequencies without damping; Actual frequencies are about 92% of above

D.L. Deflection = .0564"

Deflection per 1000# per ft. = .0393"

Stress per 1000# per ft = 920#

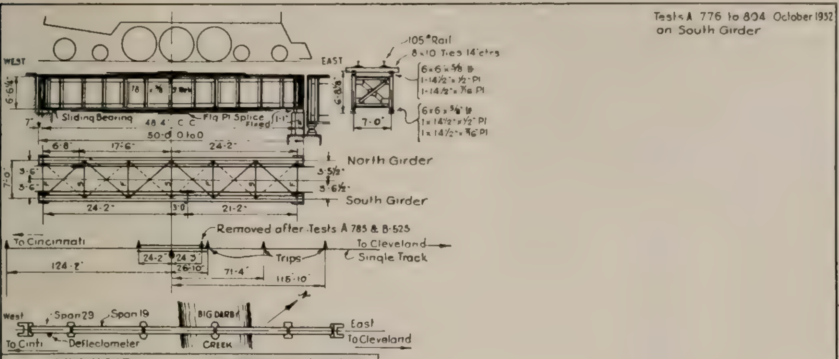
TABLE XLII

BRIDGE No.446 CHICAGO-DIV. 48'-0" C.to C. 50'-0" O.to O. D.P.G. Sheet 1 Span 28

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H	Dist "H" (Ft.)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L	L L	Imp.	Total
A-48	1	S	E	K5B I	6514	1560	2975	274.8	-	P	43.5	.266	6.77	5.95	0.91	12.90	0.3	.025	.0016	15.62	9.4	1.29	6.25	0.59	8.13
A-45	1	"	"	"	6514	"	"	"	–	"	43.5	.272	6.92	5.90	1.31	18.46	0.3	.021	.0033	6.36	7.7	"	6.39	0.49	8.17
A-55	1	"	"	"	6514	"	"	"	–	"	43.5	.288	7.34	5.77	1.51	21.28	0.3	.026	.0043	6.05	9.0	"	6.77	0.61	8.67
A-44	1	"	"	"	6514	"	"	"	–	"	43.5	292	7.44	5.73	1.96	27.85	0.3	.010	.0073	1.37	3.4	"	6.85	0.23	8.37
A-59	1	"	"	"	6506	"	"	"	9	"	43.5	.264	6.72	5.98	4.87	68.85	0.3	.095	.0448	2.12	36.0	"	6.20	2.24	9.73
A-50	1	"	"	"	6513	"	"	"	9	"	43.5	.311	7.91	5.58	5.10	72.60	0.3	.078	.0491	1.59	25.1	"	7.30	1.83	10.42
						Average					43.5	.282	7.18	5.81			0.3					1.29	6.63		
A-54	1	S	E	K3K	6460	1600	274.0	209.6	9	P	42.8	.271	6.90	5.97	4.73	66.82	0.2	.071	.0436	1.63	26.2	1.29	6.37	1.67	9.33
A-46	1	S	E	K	6401	1250	222.8	151.2	3	P	41.8	251	6.39	6.33	4.71	63.00	0.2	.028	.0342	0.82	11.1	1.29	5.90	0.66	7.85
A-56	1	"	"	"	6401	"	"	"	4	"	41.8	.247	6.29	6.37	4.80	64.25	0.2	.031	.0355	0.87	12.6	"	5.80	0.73	7.82
						Average					41.8	.249	6.34	6.35			0.2					1.29	5.85		
A-57	1	S	E	L2D	6229	2153	367.0	310.1	60	F	44.8	.319	8.12	5.73	4.31	53.03	-1.4	.067	.0465	1.44	21.0	1.29	7.49	1.57	10.35
A-47	1	S	E	L2B	6213	1844	364.0	292.3	65	F	44.8	.318	8.10	5.74	1.20	14.72	-1.4	.021	.0031	6.78	6.6	1.29	7.47	0.49	9.25
A-51	1	S	E	H10B I	223	1144	334.5	276.0	-	F	44.2	.324	8.25	5.63	3.65	41.03	5.0	.028	.0146	1.92	8.6	1.29	7.61	0.66	9.56
A-52	1	"	"	"	223	"	"	"	–	"	44.2	.318	8.10	5.68	4.51	50.75	5.0	.059	.0253	2.33	18.5	"	7.47	1.38	10.14
						Average					44.2	.321	8.17	5.65			5.0					1.29	7.54		

NOTE:-Tender weights are for full tender. Frequencies shown are theoretical frequencies without damping, actual frequencies are about 92% of above.

D.L Deflection = .0548" Deflection per 1000# per ft. = .0393" Stress per 1000# per Ft = 926#



DESIGN DATA			COMPUTED DEFLECTION (from gross M.of I.)	
Date 1902 Spec. 1901			For 1000 Lbs.per Ft.Trk.	.0255
Material Soft Steel			For 1000 Lbs.at Center	.00087
Loading E-540 E.U.L.L. 8330			D.L. Deflection	.0332
Flange Stress	D.L.	1120	D.L. Frequency	18.37
(Tens.N.Sec.)	L.L.	7170		
	Imp.	1230	**COMPUTED FROM TESTS** (using Aver.M.of I. 156930)	
	Total	9520		
Gross M.of I.at Center		184620	Deflec.1000 Lbs.per Ft.Trk.	.0300
Weight Steel per Ft.		850	Deflec.1000 Lbs.at Center	00102
Weight Deck per Ft.		450	Deflec.D.L.	.0391
Total per Ft.		1300	Frequency D.L.	1690
Total for Span 65000			Average Observed M.of I. / Comp.Gross M.of I.	.850

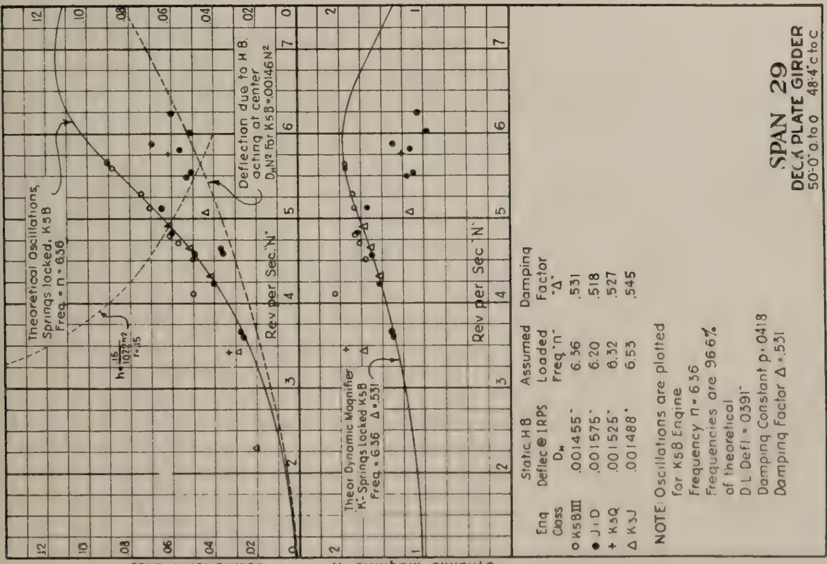
LOCOMOTIVES USED IN TESTS

Class of Engines	K3J	K3Q	K5B III	J1D						
Engines per class	2	2	5	5						
Tests per class	6	2	8	12						
Class of Engines	H5LA									
Engines per class	1									
Tests per class	1									

SPAN 29

Bridge 428 Cincinnati Div
West Span - Single Track
50-0 Deck Plate Girder

Fig. 77



Eng Class	Static H B Deflec @ 1 RPS D_H	Assumed Loaded Freq 'n'	Damping Factor 'Δ'
○ K5B III	.001455"	6.36	.531
● J1D	.001575"	6.20	.518
+ K3Q	.001525"	6.32	.527
Δ K3J	.001488"	6.53	.545

NOTE: Oscillations are plotted
for K5B Engine
Frequency n = 6.36
Frequencies are 96.6%
of theoretical
D L Defl = .0391"
Damping Constant p = .0418
Damping Factor Δ = .531

SPAN 29
DECK PLATE GIRDER
50-0" 0 to 0 48-4" c to c

Fig. 78

TABLE XLIII

BR. No. 428 CINCINNATI DIV. 50'-0" DECK PLATE GIRDER

Sheet 1 Span 29

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L.L. Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec			
No	Series			Class	Eng No.	H.B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl. (ins) "D"			R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)				D.L.	L.L.	Imp.	Total
A-798	1	S	E	J1D	6608	1691	353.0	263.8	8	P	45.7	.272	9.07	6.12	3.60	50.95	4.3	.028	.0204	1.37	10.3	1.12	7.80	0.81	9.73
A-802	"	"	W	"	6618	"	"	265.9	5	"	"	.255	8.51	6.30	3.65	51.50	"	.029	.0210	1.38	11.4	"	7.31	0.83	9.26
A-791	"	"	E	"	6618	"	"	266.8	8	"	"	.265	8.84	6.20	4.22	59.54	"	.043	.0280	1.54	16.2	"	7.60	1.23	9.95
A-795	"	"	W	"	6614	"	"	265.9	5	"	"	.228	7.60	6.62	4.57	64.50	"	.053	.0329	1.61	23.3	"	6.54	1.52	9.18
A-779	"	"	W	"	6612	"	"	265.9	5	"	"	.249	8.31	6.38	4.83	68.07	"	.066	.0368	1.79	26.5	"	7.13	1.89	10.14
A-804	"	"	E	"	6616	"	"	265.6	10	"	"	.235	7.84	6.54	5.12	72.14	"	.070	.0413	1.69	29.8	"	6.73	2.02	9.87
A-784	"	"	"	"	6612	"	"	261.7	8	"	"	.230	7.67	6.60	5.49	77.41	"	.057	.0475	1.20	24.8	"	6.60	1.64	9.36
A-797	"	"	"	"	6616	"	"	265.6	10	"	"	.242	8.08	6.45	5.54	78.23	"	.055	.0485	1.13	22.8	"	6.94	1.58	9.64
A-790	"	"	"	"	6614	"	"	265.6	9	"	"	.228	7.60	6.62	5.82	82.05	"	.062	.0533	1.16	27.2	"	6.54	1.78	9.44
A-781	"	"	"	"	6608	"	"	265.6	9	"	"	.249	8.31	6.38	5.88	82.85	"	.075	.0545	1.37	30.2	"	7.13	2.15	10.40
A-778	"	"	W	"	6618	"	"	264.2	5	"	"	.244	8.14	6.43	6.01	84.75	"	.055	.0570	.97	22.5	"	6.99	1.57	9.68
A-776	"	"	E	"	6614	"	"	261.7	8	"	"	.266	8.88	6.20	6.24	87.94	"	.065	.0613	1.06	24.5	"	7.62	1.87	10.61
					Average 12 Tests						45.7	.247	8.24	6.40			4.3					1.12	7.08		
A-794	1	S	E	K5B III	6532	1560	303.0	176.7	5	P	43.8	.235	7.84	6.48	4.10	57.94	2.4	.050	.0244	2.05	21.3	1.12	6.73	1.43	9.28
A-787	"		"	"	6537	"	"	176.7	5	"	"	.221	7.37	6.65	4.61	63.80	"	.050	.0296	1.69	22.5	"	6.34	1.43	8.89
A-792	"		W	"	6537	"	"	172.4	6	"	"	.226	7.54	6.58	4.71	66.45	"	.057	.0323	1.76	25.2	"	6.48	1.63	9.23
A-800	"		"	"	6534	"	"	176.8	6	"	"	.227	7.58	6.57	4.81	68.00	"	.061	.0337	1.81	26.8	"	6.51	1.75	9.38
A-801	"		E	"	6537	"	"	176.6	5	"	"	.223	7.45	6.62	5.12	72.40	"	.070	.0382	1.83	31.4	"	6.39	2.00	9.51
A-788	"		W	"	6535	"	"	178.2	5	"	"	.229	7.65	6.55	5.28	74.50	"	.075	.0406	1.85	32.7	"	6.56	2.14	9.82
A-785	"		"	"	6532	"	"	181.9	5	"	"	.249	8.31	6.31	5.60	79.00	"	.088	.0456	1.93	35.2	"	7.13	2.52	10.77
A-777	"		"	"	6539	"	"	175.9	5	"	"	.247	8.24	6.34	5.65	80.10	"	.090	.0465	1.94	36.5	"	7.08	2.58	10.78
					Average 8 Tests						43.8	.226	7.54	6.58			2.4					1.12	6.48		

Sheet 2 Span 29

Test		Girder	Direc. of Movement	Locomotive					Cars		Stat L.L. Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H.B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D			R.P.S. "N"	M.P.H.	Dist "H" (Ft)	Oscil (ins)				D.L.	L.L.	Imp	Total
A-799	1	S	W	K3Q	6491	1650	2955	180.8	7	P	440	225	750	679	343	4836	3.2	.035	0180	1.94	156	112	645	100	857
A-782	"	"	"	"	6495	"	"	168.6	4	"	"	.267	890	630	576	8127	"	064	.0506	126	243	"	765	186	1063
					Average 2 Tests						44.0	.246	8.20	653			3.2					112	7.05		
A-786	1	S	W	K3J	6456	1603	274.0	1467	7	P	43.2	.191	6.37	7.06	2.27	31.94	2.4	.020	.0077	260	10.4	1.12	5.48	057	7.17
A-796	"	"	"	"	6456	"	"	167.9	8	"	"	.223	7.45	663	3.43	48.36	"	.030	.0175	1.71	13.5	"	6.39	0.86	837
A-793	"	"	"	"	6457	"	"	1747	8	"	"	.205	6.84	6.87	430	6070	"	.042	.0275	153	20.5	"	5.88	120	8.20
A-780	"	"	E	"	6456	"	"	1679	5	"	"	.212	7.07	6.77	4.64	65.45	"	.052	.0320	162	245	"	608	148	868
A-803	"	"	"	"	6457	"	"	1679	9	"	"	.193	6.44	7.04	490	69.15	"	.062	.0367	169	32.1	"	554	178	8.44
A-789	"	"	"	"	6457	"	"	170.2	7	"	"	.212	7.07	6.77	5.06	7136	"	.044	.0382	1.15	20.7	"	608	126	846
					Average 6 Tests						43.2	.206	6.87	6.85			2.4					1.12	590		
A-783	1	S	W	H5LA1	6131	2092	277.8	114.2	32	F	45.0	.222	7.40	664	3.83	4345	56	.037	.0286	129	167	1.12	636	106	8.54

SPANS 30 and 31

Shallow deck girder spans, 40 ft. long over all, and 38 ft. 6 in. center to center of bearings. These spans are alike. See Fig. 79 and 80.

The measured oscillations for both spans are shown on Fig. 81. It is evident that the oscillations were unaffected by spring damping, although their magnitude was such that spring friction might have been overcome had a sufficient number of vibrations occurred.

The damping constant was found to be .0475, and the deflection factor is 1.108.

SPANS 32 and 33

Single track deck girder spans, with concrete decks and ballasted track. Length 125 ft. over all and 122 ft. 6 in. center to center of bearings. There are two girders for each span, symmetrically placed in reference to the track. See Fig. 82.

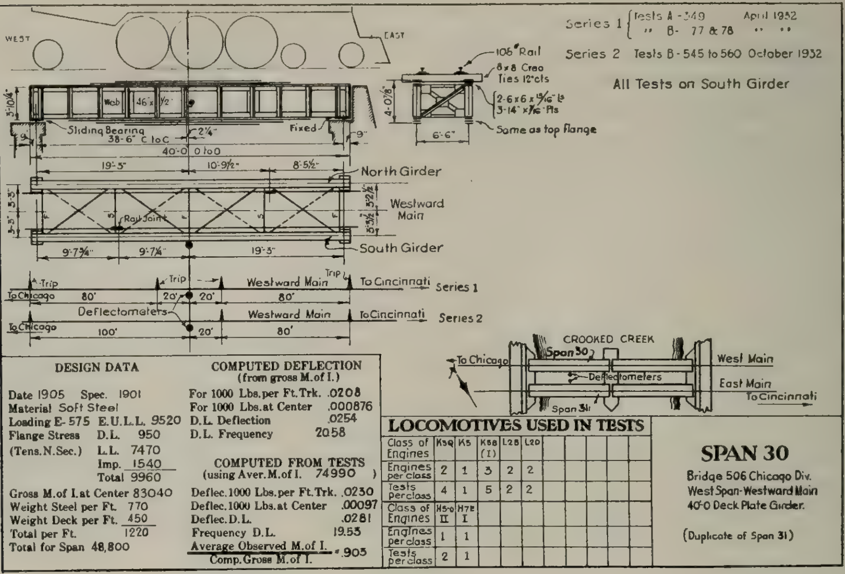
This structure is on the Pennsylvania Railroad, and three classes of engines were encountered in the tests. Higher speeds and lighter tender loads are found in the eastward movements over Span 32 than in the westward movements.

From the average deflections for the three classes in both directions, the deflection factors were found to be as follows:

	Section	
Span	*Steel Only*	*Steel and Concrete*
32	.746	1.105
33	.738	1.096

The deck slab undoubtedly acted as a part of the girder section, as the factors for the combined section correspond closely to those found for girders with open decks.

From Test A-890, recording a run of a K4-S locomotive at 3.68 r.p.s., the damping constant was found to be .0473. From Test A-891, for an M1-A locomotive running at 3.51 r.p.s., the damping constant was found to be .0478. Using a value of .047 and a frequency of 3.77, the theoretical values of the oscillations, from the K4-S locomotive, are shown in Fig. 83. It will be seen that many of them fall below the computed values. This could scarcely be due to spring damping as the oscillations were neither large enough nor rapid enough to overcome a spring friction as small as 10 per cent of the sprung weight.



Series 1 { Tests A-349 April 1932
" B- 77 & 78 " "

Series 2 Tests B-545 to 560 October 1932

All Tests on South Girder

DESIGN DATA

Date 1905 Spec. 1901
Material Soft Steel
Loading E-575 E.U.L.L. 9520
Flange Stress D.L. 950
(Tens.N.Sec.) L.L. 7470
Imp. 1540
Total 9960
Gross M.of I.at Center 83040
Weight Steel per Ft. 770
Weight Deck per Ft. 450
Total per Ft. 1220
Total for Span 48,800

COMPUTED DEFLECTION
(from gross M.of I.)

For 1000 Lbs.per Ft.Trk. .0208
For 1000 Lbs.at Center .000876
D.L. Deflection .0254
D.L. Frequency 20.58

COMPUTED FROM TESTS
(using Aver.M.of I. 74990)

Deflec.1000 Lbs.per Ft.Trk. .0230
Deflec.1000 Lbs.at Center .00097
Deflec.D.L. .0281
Frequency D.L. 19.53
$\frac{\text{Average Observed M.of I.}}{\text{Comp.Gross M.of I.}} = .905$

LOCOMOTIVES USED IN TESTS

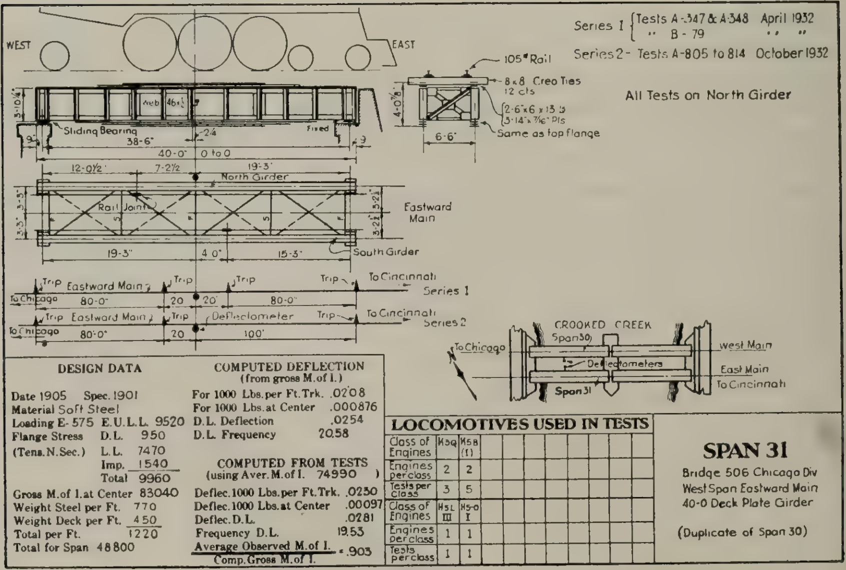
Class of Engines	K3q	K5	K5B (I)	L2B	L2D					
Engines per class	2	1	3	2	2					
Tests per class	4	1	5	2	2					
Class of Engines	H5-o II	H7E I								
Engines per class	1	1								
Tests per class	2	1								

SPAN 30

Bridge 506 Chicago Div.
West Span-Westward Main
40'-0 Deck Plate Girder.

(Duplicate of Span 31)

Fig. 79



Series I { Tests A-347 & A-348 April 1932
" B - 79 " "

Series 2 - Tests A-805 to 814 October 1932

All Tests on North Girder

DESIGN DATA

Date 1905 Spec. 1901
Material Soft Steel
Loading E-575 E.U.L.L. 9520
Flange Stress D.L. 950
(Tens.N.Sec.) L.L. 7470
Imp. 1540
Total 9960
Gross M.of I.at Center 83040
Weight Steel per Ft. 770
Weight Deck per Ft. 450
Total per Ft. 1220
Total for Span 48800

COMPUTED DEFLECTION
(from gross M.of I.)

For 1000 Lbs.per Ft.Trk. .0208
For 1000 Lbs.at Center .000876
D.L. Deflection .0254
D.L. Frequency 20.58

COMPUTED FROM TESTS
(using Aver.M.of I. 74990)

Deflec.1000 Lbs.per Ft.Trk. .0230
Deflec.1000 Lbs.at Center .00097
Deflec.D.L. .0281
Frequency D.L. 19.53
$\frac{\text{Average Observed M.of I.}}{\text{Comp.Gross M.of I.}} = .905$

LOCOMOTIVES USED IN TESTS

Class of Engines	K3q	K5B (I)								
Engines per class	2	2								
Tests per class	3	5								
Class of Engines	H5L III	H5-o I								
Engines per class	1	1								
Tests per class	1	1								

SPAN 31

Bridge 506 Chicago Div
West Span Eastward Main
40-0 Deck Plate Girder

(Duplicate of Span 30)

Fig. 80

TABLE XLIV

BRIDGE No. 506 CHICAGO-DIV 40'-0" D.P.G. WESTWARD MAIN

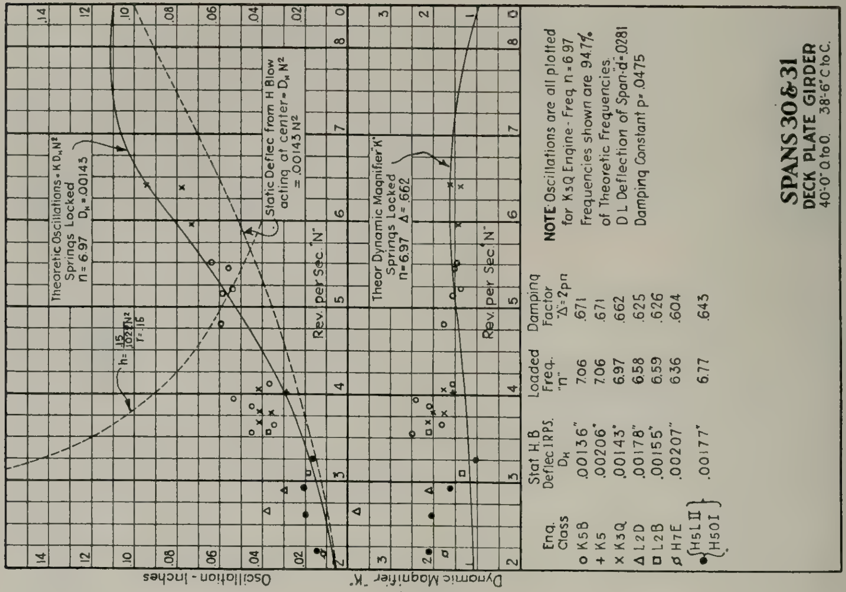
Sheet 1 Span 30

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips)		No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)							
							Eng	Tender														D L	L L	Imp	Total
B-550	2	S	W	K5B I	6513	1560	297.5	274.8	7	F	347	.188	906	708	355	501	-35	043	.0172	250	228	095	638	145	878
B-545	2	-	-	"	6506	"	-	-	7	-	370	190	915	705	365	514	-13	.033	.0182	181	17.4	095	645	112	862
A-349	1	-	-	"	6513	"	"	-	6	-	383	.192	925	703	387	545	+28	043	0204	210	224	095	652	146	893
B-553	2	"	-	-	6505	-	"	-	7	"	368	187	900	710	395	557	-1.5	051	.0212	241	272	095	635	173	903
B-77	1	-	"	K5	6525	1670	3030	-	6	-	396	204	985	684	402	567	+20	034	0220	154	166	095	693	115	903
B-558	2	-	"	K5B I	6513	1560	2975	-	7	-	389	.178	857	726	412	581	+0.6	.036	.0231	156	202	095	603	122	820
						Average					376	.190	9.14	706			-02					095	645		
B-554	2	S	W	K3Q	6487	1645	2955	2096	7	P	404	.180	868	705	368	519	+26	041	0194	212	228	095	610	139	844
B-551	"	-	-	-	6488	"	"	-	7	-	400	.180	868	705	379	535	+22	036	0205	176	199	095	610	121	826
B-547	-	"	-	-	6487	"	-	"	7	-	35.2	199	960	675	380	536	-2.6	.041	.0206	199	206	095	675	139	909
B-559	-	"	-	"	6487	"	-	-	7	-	400	.177	853	711	406	57.2	+22	.042	.0236	178	237	095	600	142	837
						Average					38.9	.184	887	699			+11					095	624		
B-557	2	S	W	L2D	6225	2155	367.0	309.6	74	F	388	202	9.75	667	266	328	-27	048	.0126	3.81	237	095	685	162	847
B-552	-	-	-	"	6229	"	-	"	51	-	377	211	1019	654	288	354	-3.8	031	.0148	209	147	095	715	105	915
						Average					382	207	997	660			-33					095	702		
B-555	2	S	W	L2B	6213	1845	364.0	283.8	51	F	379	212	10.22	660	310	382	-36	.020	0149	134	94	095	719	068	882
B-548	-	-	-	-	6211	-	"	-	43	-	388	213	1027	658	356	439	-27	.041	.0197	208	192	095	722	139	9.56
						Average					384	.213	1025	659			-31					095	722		

Sheet 2 Span 30

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency n	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier K	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips)		No	Kind	at Dist P	Defl (ins) D			R P S N	M P H	Dist H (Ft)	Oscil (ins)							
							Eng	Tender														D L	L L	Imp	Total
B-549	2	S	W	H7E I	6198	2455	3280	1836	18	F	361	.217	10.48	635	217	244	-0.8	017	.0097	175	78	0.95	735	057	887
B-556	2	S	W	H50 II	6047	2090	2753	162.0	20	F	385	198	956	712	219	247	+2.0	018	.0085	212	91	095	672	061	828
B-546	-	-	-	-	-	"	"	-	11	-	362	188	906	728	261	294	-03	025	.0121	206	133	095	637	085	817
						Average					374	193	9.31	720			+08					095	655		

NOTE · Tender weights are for full tenders
Frequencies shown are theoretical frequencies without damping. Actual frequencies are about 95% of those shown
D.L deflec = .02533"
Deflec per 1000# per ft = .0230"
Stress " " " = 779#



Eng. Class	Stat H.B Deflec 1 RPS. D_H	Loaded Freq. "n"	Damping Factor "Δ" = 2pn
o K5B	.00136"	7.06	.671
+ K5	.00206"	7.06	.671
x K3Q	.00143"	6.97	.662
Δ L2D	.00178"	6.58	.625
□ L2B	.00155"	6.59	.626
ø H7E	.00207"	6.36	.604
● H5L II H5O I	.00177"	6.77	.643

NOTE: Oscillations are all plotted for K3Q Engine - Freq. n = 6.97 Frequencies shown are 94.7%. of Theoretic Frequencies. D L Deflection of Span "d" = .0281 Damping Constant p = .0475

SPANS 30 & 31
DECK PLATE GIRDER
40'-0" O. to O. 38'-6" C to C.

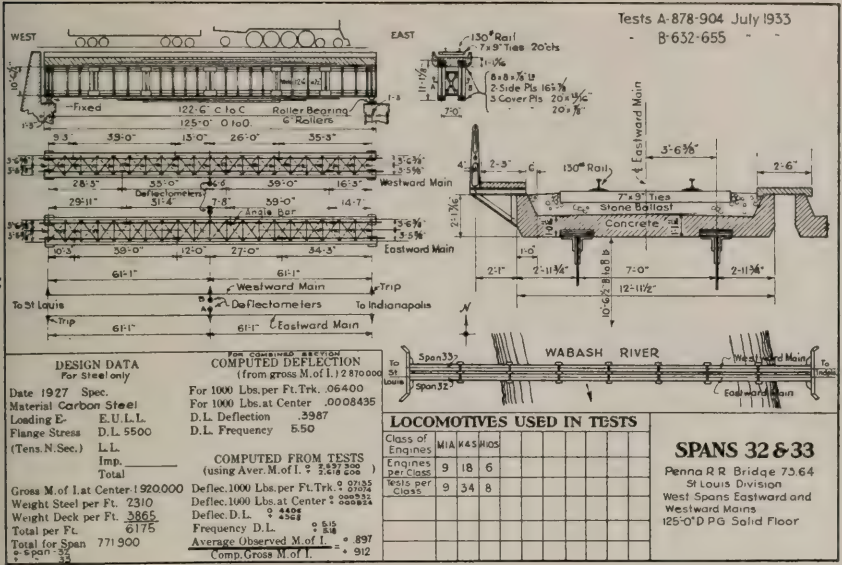
Fig. 81

TABLE XLV

BRIDGE No. 506 CHICAGO-DIV 40 FT D.P.G EASTWARD MAIN Sheet 1 Span 31

Test No.	Test Series	Girder	Direc of Movement	Locomotive Class	Eng No.	H.B at 1 RPS.	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist "P"	Stat L L Defl Defl. (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	Speed R.P.S. "N"	Speed M.P.H.	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec D.L	L L	Imp	Total
A-807	2	N	E	K5B I	6505	1560	297.5	274.8	6	P	42.8	.183	8.83	7.17	4.81	67.9	+4.5	.056	.0315	1.78	30.6	0.95	6.20	1.90	9.05
A-348	1	"	"	"	"	"	"	"	"	"	42.5	.235	11.33	6.40	5.13	72.5	+4.2	"	.0358	1.56	23.8	"	7.96	1.89	10.80
A-809	2	"	"	"	6513	"	"	"	"	"	37.8	.183	8.83	7.17	5.22	73.5	-0.5	.051	.0370	1.38	27.8	"	6.20	1.72	8.87
A-812	"	"	"	"	6505	"	"	"	"	"	36.8	.185	8.93	7.13	5.46	77.0	-1.5	.062	.0405	1.53	33.5	"	6.28	2.10	9.33
A-805	"	"	"	"	6513	"	"	"	"	"	39.8	.173	8.35	7.35	5.51	77.0	+1.5	.061	.0414	1.47	35.2	"	5.86	2.06	8.87
						Average					39.9	.192	9.25	7.04			+1.6					0.95	6.51		
A-808	2	N	E	K3Q	6487	1645	295.5	209.6	7	P	44.0	.190	9.15	6.88	5.96	84.0	+6.2	.073	.0510	1.43	38.4	0.95	6.44	2.47	9.86
A-811	"	"	"	"	6488	"	"	"	7	"	42.5	.186	8.97	6.95	6.38	90.0	+4.7	.078	.0582	1.34	41.9	0.95	6.30	2.64	9.89
A-806	"	"	"	"	6488	"	"	"	7	"	42.3	.186	8.97	6.95	6.41	90.4	+4.5	.094	.0588	1.60	50.5	0.95	6.30	3.18	10.43
						Average					42.9	.187	9.06	6.92			+5.1					0.95	6.35		
A-810	2	N	E	H5L III	6016	2090	275.7	162.0	11	F	40.5	.212	10.22	6.90	2.93	32.9	+4.2	.025	.0152	1.64	11.8	0.95	7.20	0.85	9.00
B-79	1	"	"	H5O I	6717	"	275.3	150.5	16	"	38.3	.290	13.98	5.99	3.26	36.6	+2.1	.020	.0188	1.06	6.9	0.95	9.85	0.68	11.48
						Average					39.4	.251	12.10	6.44			+3.1					0.95	8.52		

NOTE.-Tender weights are for full tender
Frequencies shown are theoretical frequencies-without damping, Actual frequencies are about 95% of above
D.L.- deflec. = .02533"
Deflec. per 1000# per ft = .0230"
Stress per " " " = 779#



DESIGN DATA
For Steel only

Date 1927 Spec.
Material Carbon Steel
Loading E- E.U.L.L.
Flange Stress D.L. 5500
(Tens. N. Sec.) L.L.
Imp. ______
Total
Gross M. of I. at Center 1 920 000
Weight Steel per Ft. 2310
Weight Deck per Ft. 3865
Total per Ft. 6175
Total for Span 771 900
○ Span 32
• " 33

FOR COMBINED SECTION
COMPUTED DEFLECTION
(from gross M. of I.) 2 870 000

For 1000 Lbs. per Ft. Trk. .06400
For 1000 Lbs. at Center .0008435
D.L. Deflection .3987
D.L. Frequency 5.50

COMPUTED FROM TESTS
(using Aver. M. of I. ○ 2 697 300, • 2 618 600)

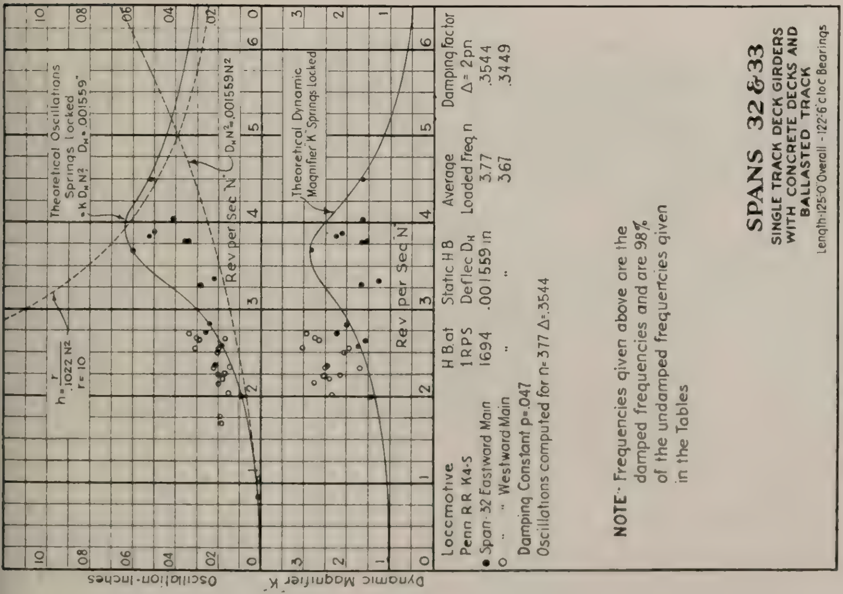
Deflec. 1000 Lbs. per Ft. Trk. ○ .07135 • .07074
Deflec. 1000 Lbs. at Center ○ .000932 • .000924
Deflec. D.L. ○ .4406 • .4568
Frequency D.L. ○ 5.15 • 5.18
$\frac{\text{Average Observed M. of I.}}{\text{Comp. Gross M. of I.}}$ = ○ .897 • .912

LOCOMOTIVES USED IN TESTS

Class of Engines	M1A	K4S	H10S
Engines per Class	9	18	6
Tests per Class	9	34	8

SPANS 32 & 33
Penna R R Bridge 73.64
St Louis Division
West Spans Eastward and Westward Mains
125'-0" D P G Solid Floor

Fig. 82



Locomotive	H.B. at 1 RPS	Static H.B. Deflec D_H	Average Loaded Freq n	Damping factor $\Delta = 2pn$
Penn R R K4-S				
● Span 32 Eastward Main	1694	.001559 in	3.77	.3544
○ " Westward Main	"	"	3.67	.3449

Damping Constant p = .047
Oscillations computed for n = 3.77 Δ = .3544

NOTE:- Frequencies given above are the damped frequencies and are 98% of the undamped frequencies given in the Tables

SPANS 32 & 33
SINGLE TRACK DECK GIRDERS WITH CONCRETE DECKS AND BALLASTED TRACK
Length 125'-0" Overall - 122'-6" c to c Bearings

Fig. 83

TABLE XLVI

DECK PLATE GIRDER WITH CONCRETE DECK-122'-6" C.TO C. BEARINGS

Sheet 1 Span 32

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net. Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L	L.L	Imp.	Total
A-884	I	N	E	K4-S	5496	1694	319.0	1330	6	P	101.1	.363	5.07	3.84	.83	11.89	21.1	.005	.0011	4.55	1.4	4.82	3.96	.06	8.84
A-885	"	"	"	"	5480	"	"	"	–	"	100.0	.361	5.04	3.84	2.00	28.48	20.0	.009	.0063	1.43	2.5	"	3.93	.10	8.85
A-903	"	"	"	"	5477	"	"	"	10	"	96.0	.362	5.06	3.84	2.35	33.64	16.0	.021	.0086	2.44	5.8	"	3.94	.23	8.99
A-880	"	"	"	"	5493	"	"	"	10	"	87.6	.364	5.09	3.84	2.57	33.69	7.6	.018	.0103	1.74	4.9	"	3.97	.18	8.97
A-904	"	"	"	"	5493	"	"	"	9	"	103.0	.367	5.13	3.83	2.64	37.65	23.0	.017	.0109	1.55	4.7	"	4.00	.19	9.01
A-889	"	"	"	"	5405	"	"	"	9	"	94.7	.356	4.97	3.85	2.73	38.92	14.7	.026	.0116	2.24	7.3	"	3.88	.29	8.99
A-878	"	"	"	"	5424	"	"	"	11	"	87.8	.362	5.06	3.84	2.83	40.42	7.8	.025	.0125	2.00	6.9	"	3.94	.27	9.03
A-896	"	"	"	"	5478	"	"	"	9	"	95.5	.367	5.13	3.83	3.27	46.30	15.5	.028	.0167	1.67	7.6	"	4.00	.30	9.12
A-888	"	"	"	"	5499	"	"	"	11	"	97.7	.372	5.20	3.82	3.35	47.79	17.7	.022	.0175	1.26	5.9	"	4.05	.24	9.11
A-890	"	"	"	"	5477	"	"	"	9	"	96.7	.372	5.20	3.82	3.68	52.56	16.7	.060	.0211	2.84	16.1	"	4.05	.65	9.52
A-897	"	"	"	"	5496	"	"	"	9	"	97.8	.357	4.99	3.85	3.79	54.11	17.8	.036	.0224	1.61	10.1	"	3.89	.39	9.10
A-900	"	"	"	"	5477	"	"	"	-	"	92.2	.361	5.04	3.84	3.79	54.14	12.2	.034	.0224	1.52	9.4	"	3.93	.37	9.12
A-901	"	"	"	"	5427	"	"	"	11	"	93.0	.378	5.28	3.81	3.84	54.86	13.0	.052	.0230	2.26	13.8	"	4.12	.57	9.51
A-892	"	"	"	"	5491	"	"	"	8	"	95.3	.386	5.39	3.79	3.89	55.60	15.3	.050	.0236	2.12	12.9	"	4.21	.54	9.57
A-882	"	"	"	"	5421	"	"	"	9	"	95.1	.372	5.20	3.82	4.03	57.58	15.1	.041	.0253	1.62	11.0	"	4.05	.45	9.32
A-895	"	"	"	"	5420	"	"	"	11	"	95.5	.382	5.34	3.80	4.50	64.35	15.5	.052	.0316	1.64	13.6	"	4.16	.57	9.55
							319.0	133.0			95.6	.368	5.15	3.83			15.6					4.82	4.01		
					D_H =	.001563 in.																			

Sheet 2 Span 32

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D L	L L	Imp	Total
A-887	I	N	E	M1-A	6789	1850	390.0	268.7	91	F	103.1	.421	5.88	3.71	2.02	25.94	20.0	.014	.0069	2.03	3.3	4.82	4.59	.15	9.56
A-899	"	"	"	"	6778	"	"	"	74	"	104.1	.415	5.80	3.72	2.02	25.94	21.0	.016	.0069	2.32	3.8	"	4.52	.17	9.51
A-902	"	"	"	"	6796	"	"	"	67	"	96.5	.459	6.41	3.65	2.06	26.47	13.4	.025	.0072	3.47	5.4	"	5.00	.27	10.09
A-893	"	"	"	"	6793	"	"	"	70	"	104.0	.452	6.31	3.66	2.20	28.32	20.9	.012	.0082	1.46	2.6	"	4.93	.13	9.88
A-883	"	"	"	"	6784	"	"	"	77	"	103.0	.442	6.17	3.66	2.89	37.11	19.9	.040	.0141	2.83	9.0	"	4.82	.43	10.07
A-891	"	"	"	"	6792	"	"	"	76	"	100.5	.436	6.09	3.67	3.51	45.17	17.4	.061	.0208	2.93	14.0	"	4.75	.67	10.24
				Average	East	Bound	390.0	268.7			101.8	.438	6.12	3.67			18.7					4.82	4.77		
				D_H=.001693in.																					
A-898	I	N	E	H10-S	9418	1830	247.5	123.0	69	F	92.7	.311	4.34	3.97	0.46	5.21	14.2	.005	.0003	10.67	1.6	4.82	3.39	.08	8.29
A-881	"	"	"	"	8809	"	"	"	44	"	88.5	.334	4.67	3.92	1.09	12.29	10.0	.010	.0020	5.00	3.0	"	3.64	.11	8.57
A-886	"	"	"	"	9919	"	"	"	50	"	96.3	.341	4.76	3.90	2.16	24.27	17.8	.022	.0078	2.82	6.3	"	3.72	.23	8.77
A-894	"	"	"	"	7024	"	"	"	55	"	99.6	.329	4.60	3.93	2.43	27.37	21.1	.014	.0099	1.41	4.2	"	3.59	.15	8.56
A-879	"	"	"	"	8813	"	"	"	62	"	98.0	.311	4.34	3.97	2.76		19.5	.024	.0128	1.85	7.9	"	3.39	.27	8.48
		Average East Bound					247.5	123.0			95.0	.325	4.54	3.94			16.5					4.82	3.54		
				NOTE:- Unit Stresses are based on combined Section of Steel and Concrete Deck																					
				D_H=.001678 in.																					

TABLE XLVII

DECK PLATE GIRDER WITH CONCRETE DECK - 122'-6" c to c BEARINGS

Sheet 1 Span 33

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D			R P S 'N'	M P H	Dist 'H' (Ft)	Oscil (ins)				D L	L L	Imp	Total
B 643	1	S	W	K4-S	5496	1694	3190	1955	8	P	1031	397	561	3.77	1.03	1471	231	.005	.0017	292	13	482	437	06	925
B-641	"	"	"	"	5421	"	"	"	8	"	1010	423	595	372	1.69	2409	210	018	0046	391	42	"	466	.20	968
B-646	"	"	"	"	5499	"	"	215.5	13	"	1023	.412	582	375	176	2507	223	019	0048	396	46	"	454	.21	957
B-648	"	"	"	"	5477	"	"	1955	8	"	1010	417	589	3.74	202	2878	210	015	.0064	234	36	"	460	17	959
B-636	"	"	"	"	5477	"	"	"	8	"	917	.408	577	375	215	3071	117	020	.0072	278	49	"	450	.22	954
B-654	"	"	"	"	5420	"	"	"	13	"	965	.430	608	370	219	3128	165	018	0075	240	42	"	474	20	976
B-650	"	"	"	"	5472	"	"		9	"	985	430	608	3.70	223	3181	185	.020	.0078	256	47	"	474	.22	978
B-649	"	"	"	"	5481	"	"	1955	8	"	975	.415	586	374	225	3218	175	.017	.0079	215	41	"	457	19	958
B-635	"	"	"	"	5490	"	"	"	8	"	978	420	593	3.73	237	33.79	178	015	0088	170	36	"	463	17	962
B-638	"	"	"	"	5420	"	"	2155	12	"	980	.426	6.00	3.71	237	3382	180	022	.0088	250	52	"	469	24	975
B-644	"	"	"	"	5475	"	"		9		1025	.429	606	3.70	250	3574	225	.020	0098	209	47	"	473	22	977
B-647	"	"	"	"	5493	"	"	2155	7	"	1036	.408	577	3.75	2.54	3623	236	.020	0101	198	49	"	4.50	22	954
B-637	"	"	"	"	5492	"	"		9	"	99.8	.420	593	373	255	3641	19.8	.031	.0101	3.07	74	"	463	.34	979
B-640	"	"	"	"	5478	"	"	2155	7	"	912	.405	572	375	265	3784	112	029	.0110	264	72	"	446	.32	960
B-633	"	"	"	"	5405	"	"	"	7	"	972	.414	5.85	374	266	3798	172	.030	.0110	273	72	"	456	33	971
B-634	"	"	"	"	5499	"	"	"	9	"	97.4	.425	599	371	271	3871	17.4	.034	.0115	295	80	"	468	.37	987
			Average West Bound				319.0	2065			987	417	589	3.74			18.7					482	460		
				D_H = .001563 in																					

Sheet 2 Span 33

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No.	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) D			R P S 'N'	M.P.H	Dist 'H' (Ft)	Oscil (ins)				D L	L L	Imp	Total
B-639	1	S	W	M1-A	6778	1850	3900	354 9	98	F	1080	494	698	3.57	138	1775	249	.014	.0032	437	28	482	544	15	10.41
B-653	"	"	"	"	6786	"	"	"	85	"	1060	504	712	355	186	2386	229	.019	.0058	327	37	"	555	21	1058
B-645	"	"	"	"	6779	"	"	"	58	"	1062	492	6.95	357	190	2438	231	.020	.0061	327	41	"	542	.22	10.46
			Average West Bound				3900	3549			1067	.497	702	356			23.6					482	548		
				D_H = 001693 in																					
B-652	1	S	W	H10-S	9418	1830	2475	1754	45	F	944	351	496	388	151	1702	159	011	0038	297	31	482	387	12	881
B-651	"	"	"	"	8598	"	"	"	20	"	973	.311	439	3.98	192	2163	188	.012	0062	193	39	"	343	13	838
B-642	"	"		"	9418	"		"	7	"	1015	335	473	392	258	290	230	025	.0112	223	73	"	369	27	878
			Average West Bound				247.5	1754			977	.332	469	392			192					482	366		
				D_H = .001878 in																					
			NOTE Unit Stresses are based on Combined Section of Steel and Concrete																						

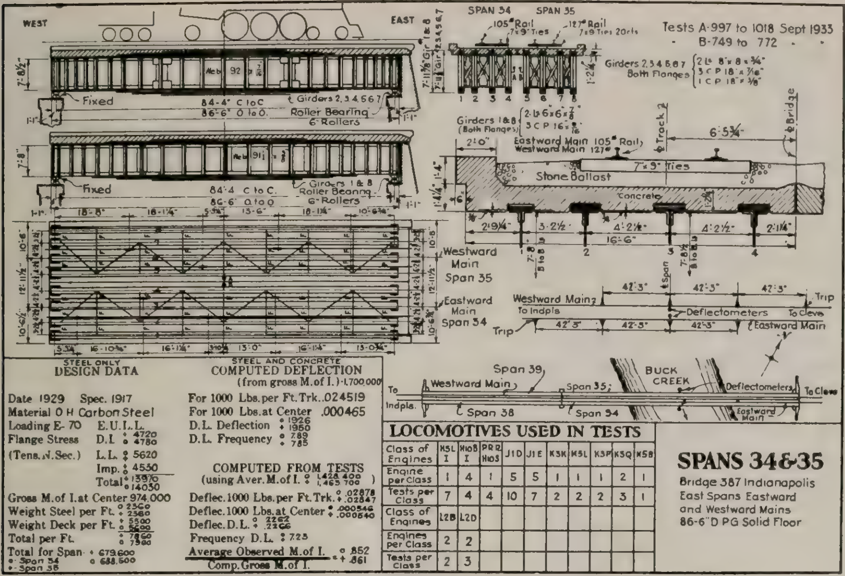
SPANS NOS. 34 and 35

Deck girder spans, with concrete decks and ballasted track. Length over all 86 ft. 6 in.; center to center of bearings 84 ft. 3 in. There are four girders in each group. The spans are alike, but the rail in the eastward main (span 34) is lighter than that in the westward main (span 35), giving different dead load deflections. See Fig. 84.

Deflections were taken on the inner girders only, that is, girder No. 4 in span 34, and girder No. 5 in span 35, so that we have no direct measurement of the distribution of load between the girders. In span 36 it was found that the load taken by the inner girders was about 1.23 of the average for the group, and for span 39 this factor was found to be 1.25. Assuming a value of 1.24 for these spans, the deflection factors are found to be 1.174 for span 34 and 1.162 for span 35. These are about what might be expected, and they are probably within 1 or 2 per cent of the actual values.

The damping factors and constants can be determined from the readings on any girder, and the value of p was found to be .0345. This seems quite low, but the oscillations in the span are clear and well marked. For the 70 ft. spans (36 and 37) the value of p was found to be .059, and the high value may be due in part to the fact that those spans have sliding instead of roller bearings. But for the 125 ft. girders (32 and 33) which are also equipped with roller bearings, the damping constant was found to be .047 which is too high, considering the small damping factor found for these 86 ft. spans. It may be that there was an unusually large amount of friction in the rollers of spans 32 and 33, which accounts for the inconsistency.

The theoretical and measured oscillations are shown in Fig. 85. Evidently there was some damping from the locomotive springs at the higher speeds.



STEEL ONLY
DESIGN DATA

Date 1929 Spec. 1917
Material O H Carbon Steel
Loading E-70 E.U.L.L.
Flange Stress D.I. + 4720 ∘ 4780
(Tens. N. Sec.) L.L. ∘+ 5620
Imp. +∘ 4530
Total + 13970 ∘ 14030
Gross M. of I. at Center 974,000
Weight Steel per Ft. ∘ 2360 + 2380
Weight Deck per Ft. + 5500 ∘ 5600
Total per Ft. + 7860 ∘ 7980
Total for Span + 679,600 ∘ 688,500
∘ - Span 34
+ - Span 35

STEEL AND CONCRETE
COMPUTED DEFLECTION
(from gross M. of I.) - 1,700,000

For 1000 Lbs. per Ft. Trk. .024519
For 1000 Lbs. at Center .000465
D.L. Deflection ∘ .1926 + .1950
D.L. Frequency ∘ 7.89 + 7.85

COMPUTED FROM TESTS
(using Aver. M. of I. ∘ 1,428,400 + 1,465,700)

Deflec. 1000 Lbs. per Ft. Trk. ∘ .02878 + .02847
Deflec. 1000 Lbs. at Center ∘ .000546 + .000540
Deflec. D.L. ∘ .2262 + .2266
Frequency D.L. ∘+ 7.25
Average Observed M. of I. / Comp. Gross M. of I. = ∘ .852 + .861

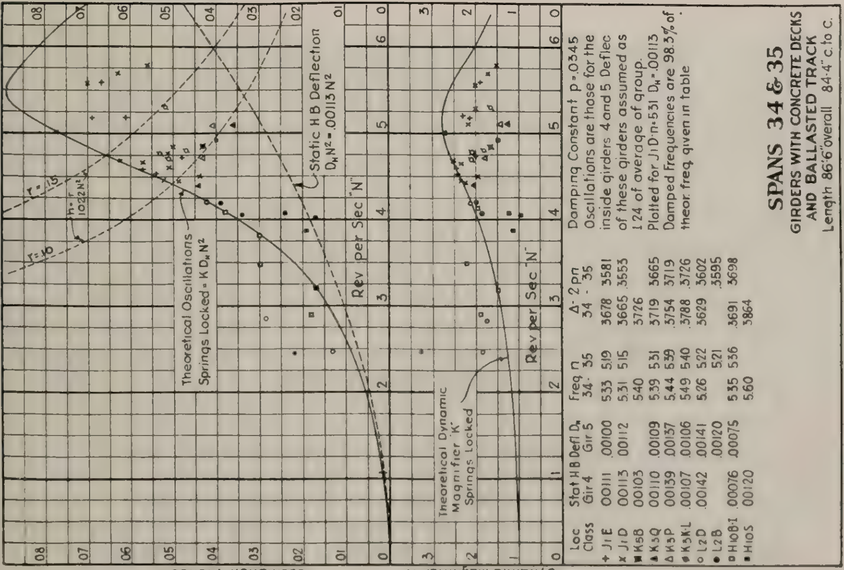
LOCOMOTIVES USED IN TESTS

Class of Engines	K5L I	H10B I	PRR H10S	J1D	J1E	K3K	K5L	K3P	K3Q	K5B
Engine per Class	1	4	1	5	5	1	1	1	2	1
Tests per Class	7	4	4	10	7	2	2	2	3	1
Class of Engines	L2B	L2D								
Engines per Class	2	2								
Tests per Class	2	3								

SPANS 34 & 35

Bridge 387 Indianapolis
East Spans Eastward
and Westward Mains
86-6" D PG Solid Floor

Fig. 84



Loc Class	Stat H B Defl D_H Gir 4	Gir 5	Freq n 34	35	Δ - 2pn 34	35
+ J1E	.00111	.00100	5.33	5.19	.3678	.3581
× J1D	.00113	.00112	5.31	5.15	.3665	.3553
■ K5B	.00103		5.40		.3726	
▲ K3Q	.00110	.00109	5.39	5.31	.3719	.3665
△ K3P	.00139	.00137	5.44	5.39	.3754	.3719
● K3K-L	.00107	.00106	5.49	5.40	.3788	.3726
○ L2D	.00142	.00141	5.26	5.22	.3629	.3602
● L2B		.00120		5.21		.3595
□ H10B-I	.00076	.00075	5.35	5.36	.3691	.3698
■ H10S	.00120		5.60		.3864	

Damping Constant p = .0345
Oscillations are those for the inside girders 4 and 5 Deflec of these girders assumed as 1.24 of average of group.
Plotted for J1D n = 5.31 D_H = .00113
Damped Frequencies are 98.3% of theor. freq. given in table

SPANS 34 & 35
GIRDERS WITH CONCRETE DECKS AND BALLASTED TRACK
Length 86'-6" overall 84-4" c. to c.

Fig. 85

TABLE XLVIII

DECK PLATE GIRDER WITH CONCRETE DECK AND BALLASTED TRACK - LENGTH 86'-6"- 84'-3" C to C

Sheet 1 Span 34

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_N N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips)		No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)				DL	LL	Imp	Total
							Eng	Tender																	
A-997	I	4	E	J1E	6626	1672	3515	196.0	9	P	70.1	223	6.24		517	7293	8 8	060	0297	202	269	4.04	3.21	.86	8.11
A-1004	··	4	·	·	6628	·	·	2054	8	··	72.0	.231	647		519	73.17	10.7	.068	.0299	227	295	··	3.32	98	834
A-1018	-	4	··	··	6627	··	-	1980	9	··	73.7	.226	633		5.58	7868	124	066	.0346	190	29.2	·	325	.95	824
				Average	Girder	4	3515	199.8			719	.227	636	542			106					4.04	327		
A-1011	I	4	E	J1D	6611	1691	353.0	2020	8	P	700	231	647		465	6556	87	057	0244	2.33	247	404	332	82	818
A-999	··	4	·	-	6610	··	··	1871	8	-	664	.230	6.44		5.58	7868	5.1	070	.0352	199	30.4	··	331	101	8.36
A-1012	-	4	··	·	6618	·	··	1875	8	··	793	.225	630		5.69	8028	180	.063	.0366	172	28.0	··	3.24	91	819
A 1005	-	4	··	··	6613	-	·	1863	8	-	695	.228	639		579	8169	8.2	.056	.0379	1.48	246	-	3.28	81	813
				Average	Girder	4	353.0	1907			71.3	.229	641	5.40			10.0					4.04	3.29		
A-1002	I	4	F	K5B III	6538	1560	302.0	1748	5	P	71.1	.213	5.96	549	485	6839	9.8	.039	.0242	161	183	404	3.07	.56	767
A-1000	I	4	E	K3Q	6495	1650	295.5	1499	8	-	703	.215	602		438	6181	9.6	.043	.0209	206	20.0	404	3.09	.62	775
A-1013	··	4	-	··	6495	··	··	159.9	4	-	75.1	.219	6.13		5.10	71.90	14.4	.035	.0283	1.23	16.0	-	315	.50	7.69
				Average	Girder	4	295.5	154.9			72.7	.217	6.08	5.48			12.0					4.04	3.12		
A-1006	I	4	F	K3 P I	6479	2076	2802	1530	3	P	76.8	.207	580	553	5.09	68.12	16.1	.050	.0360	1.39	24.1	4.04	2.98	.72	7.74
A-1016	I	4	E	K3k	6466	1603	274.0	1535	5	P	67.5	.198	5.54		4.80	6767	6.8	.044	.0246	179	22.2	4.04	285	.63	7.52
A-1009	··	4	-	K3L	6474	··	·	146.0	5	-	633	.196	5.48		530	7474	26	.049	0301	163	250	··	282	.70	7.56
							2740	1498			65.4	.197	5.51	5.59			4.7					4.04	283		

Sheet 2 Span 34

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency "n"	Speed		Hammer Blow		Stat. Defl H Blow $D_N N^2$ at Center	Dynamic Magnifier "K"	Impact %	Moment Unit Stress (Kips) Tens. Net Sec			
No.	Series			Class	Eng No.	H B at 1RPS	Weight (Kips)		No	Kind	at Dist "P"	Defl (ins) "D"			R.P.S. "N"	M.P.H	Dist. "H" (Ft)	Oscil (ins)				D.L	LL	Imp	Total
							Eng	Tender																	
A-1014	I	4	E	L2D	6231	2163	367.0	270.0	76	F	81.6	.240	6.72	5.35	2.47	30.36	17.3	.016	.0087	1.84	6.6	4.04	3.45	.23	7.72
A-1007	I	4	E	H10B-I	219	1188	334.5	240.3	69	F	70.0	.223	6.24	544	3.17	35.61	12.8	.011	.0076	1.45	4.9	4.04	3.21	.16	7.41
A-1010	I	4	E	Penn. H-10-S	8594	1830	2475	—	14	F	700	.177	4.96		3.88	43.65	10.7	020	.0181	1.11	11.3	4.04	2.55	.29	6.88
A-998	-	4	·	··	8594	··	··	—	19	··	68.0	.174	4.87		4.03	44.58	8.7	.018	.0195	.92	10.4	·	2.50	.26	6.80
A-1003	·	4	··	-	8594	·	·	—	8	-	661	.181	5.06		4.06	44.88	6.8	.025	0198	1.21	13.8	-	2.60	.36	7.00
A-1017	-	4	··	-	8594	-	··	—	15	··	677	.178	499		4.91	55.23	8.4	.043	.0289	1.49	24.2	-	2.56	.62	7.22
				Average	Girder	4	247.5	—			67.9	.178	499	5.70			8.6					4.04	2.56		
A-1001	I	4	E	H6-L I	6035	2090	2757	120.7	7	F	71.0	.199	5.57		2.19	24.63	11.7	.007	.0064	1.09	3.5	4.04	286	.10	7.00
A-1015	··	4	-	··	6035	·	··	122.8	5	-	72.0	.195	5.46		2.61	29.40	12.7	.014	.0081	1.73	7.2	·	281	.20	7.05
A-1008	-	4	··	··	6035	-	··	122.5	6	-	67.5	.200	5.60		3.28	36.82	8.2	.023	.0143	1.61	11.5	·	288	.33	7.25
				Average	Girder 4		275.7				70.2	.198	554	5.58			10.9					404	2.85		

NOTE:-The E.U.L.L., Frequencies and Live Load Stress, are the average for the girder group acting as a unit

The deflections and oscillations in girder 4 are assumed to be 1.24 times those for the group.

TABLE XLIX

DECK PLATE GIRDER WITH CONCRETE DECK AND BALLASTED TRACK · LENGTH · 86'6" · 84'4" C to C. Sheet 1 Span 35

Test No	Series	Girder	Direc of Movement	Locomotive Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Kind	Stat L. Defl at Dist "P"	Defl (ins) D	E U L L (Kips)	Loaded Frequency 'n'	Speed R P S 'N'	M P H	Hammer Blow Dist 'H' (Ft)	Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
B-768	1	5	W	J1E	6621	1672	3515	2819	10	P	825	254	719		246	3471	212	022	0067	327	86	409	370	32	811
B-763	-	5	-	..	6626	-	-	2819	10	-	761	253	716		452	6373	148	054	0225	240	213	-	368	78	855
B-769	-	-	.	-	6629	..	-	2873	13	.	801	.254	719		459	6472	188	056	0232	241	220	.	370	81	860
B-761	.	-	..	..	6627	..	..	2873	12	..	77.4	.254	719		4.72	6631	161	047	0245	199	185	.	370	.68	847
				Average	Girder	5	351.5	2846		.	790	254	719	528			177					409	370		
B-755	1	5	W	J1D	6611	1691	3530	2859	12	P	817	263	744		444	6760	204	049	0221	222	186	409	382	69	860
B-756	-	-	..	"	6610	-	-	2852	.	-	73.7	263	744		446	6289	124	052	.0223	233	197	.	382	75	866
B-760	-	..	-	..	6615	..	-	2829	9	-	822	259	733		450	6347	209	044	0227	194	170	-	377	64	850
B-754	..	-	..	..	6618	..	-	2834	6	-	812	256	726		460	6486	199	051	0237	215	200	-	373	75	857
B-749		-	..	-	6613	..	..	284.5	11	..	735	.264	747		478	6740	12.2	051	.0256	199	19.3	..	3.84	74	867
B-770	-	-	-	-	6618	.	..	2865	9	.	825	259	733		469	6613	212	062	.0246	252	240		377	90	8.76
				Average	Girder	5	353.0	2847			791	261	739	525			178					409	380		
B-758	1	5	W	K3Q	6493	1650	2955	190.9	4	P	786	229	648	540	5.00	70.47	179	075	.0272	275	327	409	3.32	109	850
B-772	1	5	W	K3 P1	6479	2076	2802	1802	3	P	742	215	608	548	471	6639	135	053	0304	174	247	409	313	77	799
B-752	1	5	W	K3L	6474	1603	274 0	182.0	5	P	75.2	.213	6 02		472	66.54	145	.048	0236	203	225	409	309	70	788
B-765	-	5	.	K3K	6466	..	-	1827	4	-	77.4	215	6.08		478	6740	16.7	050	.0242	207	23.3	.	313	73	795
				Average	Girder	5	2740	182.3			763	214	6.05	5.49			156					409	311		

Sheet 2 Span 35

Test No	Series	Girder	Direc of Movement	Locomotive Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	Cars No	Kind	Stat L. Defl at Dist "P"	Defl (ins) D	E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed R.P.S 'N'	M.P.H	Hammer Blow Dist 'H' (Ft)	Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'k'	Impact %	Moment Unit Stress (Kips) Tens Net Sec DL	LL	Imp	Total
B-753	1	5	W	L2D	6231	2153	3670	2768	59	F	70.0	.240	6.79		3.82	4695	57	.036	.0206	1.75	15.0	409	349	53	811
B-767	-	..	-	{ "	6233	"	..	275.7	72	"	79.8	.252	7.13		4.19	51.54	15.5	.053	.0248	214	210	-	366	77	852
D.H }				L2B	6224																				
				Average	Girder	5	367.0	276.2			74.9	.246	6.96	5.31			10.6					409	358		
B-759	1	5	W	L2B	6212	1844	364.0	258.0	46	F	711	.250	708		4.06	4994	6.8	.037	.0198	187	148	409	3.64	54	8.27
B-767	-	..	..	{ -	6224	-	-	257.8	72	..	74.7	250	7.08		4.19	5154	10.4	.042	.0211	199	16.8	-	364	61	834
D.H.				L2D	6233																				
				Average	Girder	5	364.0	2579			72.9	.250	708	530			8.6					409	364		
B-751	1	5	W	H10B-I	227	1188	3345	214.8		F	748	244	6.91		2.89	3248	176	012	.0063	1.90	49	409	3.55	17	781
B-766	.	5	.	-	239	-	-	216.6		-	770	235	665		3.49	39.26	198	.020	0091	220	88	-	342	30	781
B-762	.	5	.	..	229	-	-	216 6		-	72.8	.237	6 71		4.13	4644	15.6	025	0128	195	106	..	345	.37	771
				Average	Girder	5	3345	216.1			749	.239	676	5.35			177					409	347		
B-750	1	5	W	H6L1	6035	2090	275.7	120.5	4	F	68.0	.209	5.91		1 87	2098	8.7	.008	.0046	174	39	409	304	12	725
B-757	.	5	-	.	6035	.	-	117.1	20	.	711	.208	588		3.06	34.36	118	.018	.0126	143	8.7	.	302	27	738
B-764	.	5	.	.	6035	.	.	118.8	15	.	685	.206	583		3.24	3631	72	023	0138	167	111	.	300	33	742
B-771	.	5	.	.	6035	.	.	119.9	3	.	75.5	212	600		3.29	36.93	162	017	.0142	113	80		308	25	742
				Average	Girder	5		1191			708	209	591	552			115					409	304		

NOTE · The E U L L, Frequencies and L L Stress are the average for the girder group acting as a unit

The deflections and oscillations in girder 5 are assumed to be 1 24 times those for the group

SPANS 36 and 37

Single track deck girder spans, with concrete decks and ballasted track. Length 70 ft. over all; 67 ft. 9 in. center to center of bearings. There are three girders, all alike, under each track, the center of the track being 1 ft. 9 in. from the center of the group. The two spans are alike. See Fig. 86.

Most of the readings were taken on the inner girder of each span, that is, on girder 3 of span 36, and girder 4 of span 37. A few simultaneous readings, however, were taken on the outer (1) and center (2) girders of span 36. From these deflections, it was found that the deflection of the three girders, bears the following proportion to the average vertical deflection of the group, acting as a unit:

		Girder	
Eng. Class	*No. 1* (outer)	*No. 2* (center)	*No. 3* (inner)
J1-D	.790	.929	1.231
L2-D	.776	.923	1.234
L2-B	.797	.923	1.231
Average	.788	.925	1.232

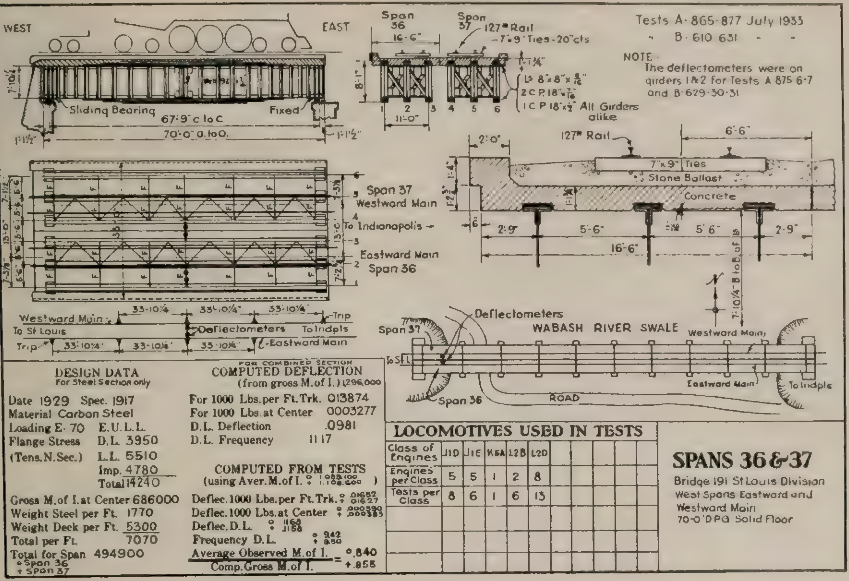
For some reason span No. 37 is slightly stiffer than span No. 36. This is apparent for all classes of engines from the oscillations, as well as the measured crawl deflections. Assuming that the distribution of load between the three girders is the same for span 37, as found in span 36, the following deflection factors are obtained, and they check closely for all types of engines.

Span No.	*Steel Only*	*Combined Section*
36	.639	1.190
37	.627	1.169

From these factors it will be seen that the concrete deck was acting as part of the girder section.

The actual and theoretical oscillations, for the inner girders (3 and 4) of both spans, are shown in Fig. 87. The measured values agree well with the computed values. There is very little magnification, the maximum being about 1.40. This is due to the large amount of damping, the constant, p, being found to have a value of .059, which is about what might be expected in deck girder, with an open deck, 25 or 30 ft. in length.

Due to the stiffness of the spans, their loaded frequency is 6.50, and the locomotives used in the tests are the heaviest in service on the railroad. There is no indication of spring damping, but the oscillation at the fastest run (5.96 r.p.s.), was scarcely of sufficient magnitude to overcome 15 per cent friction in the locomotive springs.



Tests A-865-877 July 1933
" B-610 631 " "

NOTE-
The deflectometers were on girders 1&2 for Tests A 875 6-7 and B-629-30-31

DESIGN DATA
For Steel Section only

Date 1929 Spec. 1917
Material Carbon Steel
Loading E-70 E.U.L.L.
Flange Stress D.L. 3950
(Tens.N.Sec.) L.L. 5510
Imp. 4780
Total 14240

Gross M. of I. at Center 686000
Weight Steel per Ft. 1770
Weight Deck per Ft. 5300
Total per Ft. 7070
Total for Span 494900
○ Span 36
+ Span 37

FOR COMBINED SECTION
COMPUTED DEFLECTION
(from gross M. of I.) 1296,000

For 1000 Lbs. per Ft. Trk. 013874
For 1000 Lbs. at Center 0003277
D.L. Deflection .0981
D.L. Frequency 11 17

COMPUTED FROM TESTS
(using Aver. M. of I. ○ 1.088,100 + 1.108,600)

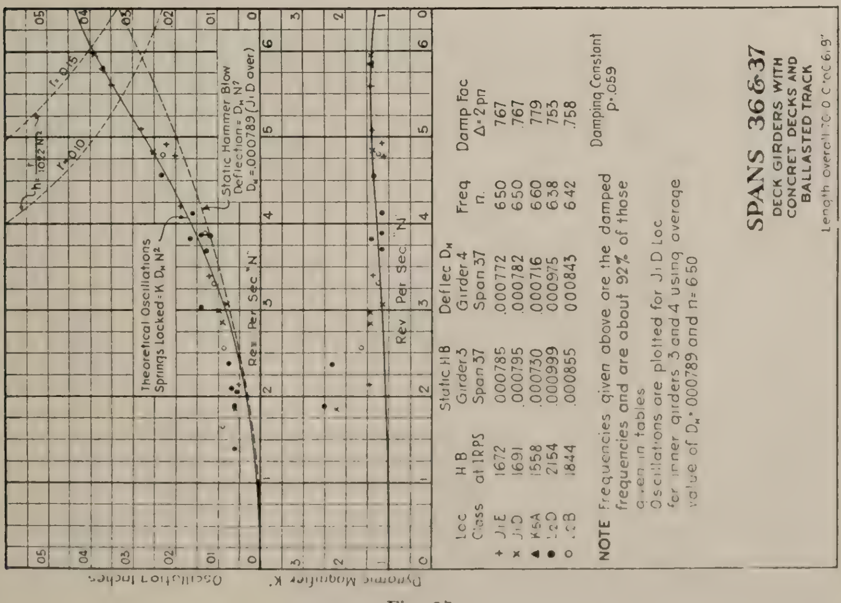
Deflec. 1000 Lbs. per Ft. Trk. ○ .01682 + .01627
Deflec. 1000 Lbs. at Center ○ .000390 + .000383
Deflec. D.L. ○ .1168 + .1158
Frequency D.L. ○ 9.42 + 9.50
$\frac{\text{Average Observed M. of I.}}{\text{Comp. Gross M. of I.}}$ = ○ .840 + .856

LOCOMOTIVES USED IN TESTS

Class of Engines	J1D	J1E	K5A	L2B	L2D					
Engines per Class	5	5	1	2	8					
Tests per Class	8	6	1	6	13					

SPANS 36 & 37
Bridge 191 St Louis Division
West Spans Eastward and Westward Main
70-0" D P G Solid Floor

Fig. 86



Loc Class	H B at 1RPS	Static HB Girder 3 Span 37	Deflec D_H Girder 4 Span 37	Freq n.	Damp Fac Δ = 2pn
+ J1E	1672	000785	.000772	650	767
× J1D	1691	.000795	.000782	650	.767
▲ K5A	1558	.000730	.000716	660	779
● L2D	2154	.000999	000975	638	753
○ L2B	1844	.000855	000843	642	.758

Damping Constant
p = .059

NOTE Frequencies given above are the damped frequencies and are about 92% of those given in tables
Oscillations are plotted for J1 D Loc for inner girders 3 and 4 using average value of D_H = 000789 and n = 650

SPANS 36 & 37
DECK GIRDERS WITH CONCRETE DECKS AND BALLASTED TRACK
Length overall 70-0 C to C 67-9"

Fig. 87

TABLE L

DECK PLATE GIRDER SPAN WITH CONCRETE DECK AND BALLASTED TRACK-70FT LONG - 67'-9" C to C. Sheet 1 Span 36

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E U L L (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow D_{N^2} at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1 RPS	Weight (Kips)		No	Kind	at Dist "P"	Defl (ins) D			R P S "N"	M P H	Dist "H" (Ft)	Oscil (ins)				D L	L L	Imp	Total
							Eng	Tender																	
B 620	1	3	E	J1E	6620	1672	3515	300.7	10	P	655	146	715		213	3003	124	005	.0035	1.43	3.4	330	336	.11	677
B-621		3	"	"	6629	"	"	2937	10	"	650	154	755		477	6718	119	020	0178	112	129	"	355	.46	731
A-872		3	"	"	6620	"	"	265.9	10	"	606	.151	740		492	6941	75	.022	0189	116	145	"	348	.50	728
B-612	"	3		"	6621	"	"	2695	11	"	625	157	770		508	7167	94	028	0202	138	178	"	362	.64	756
B-611	"	3	"	"	6626	"	"	2659	12	"	660	.157	770		560	7895	129	.035	0246	142	223	"	362	.81	773
			Average-Girder 3			- E Bound		2791			639	.153	750	7.07			108					330	353		
B-616	1	3	W	J1D	6600	1691	353.0	3012	13	P	670	.150	735		185	2607	13.9	006	0027	222	40	330	355	.14	699
B 630	"	2	E	"	6607	"	"	2629	10	"	620	114	745		399	5623	8.9	.013	0110	1.18	107	"	350	.37	717
A-876	"	1	"	"	"	"	"	"	"	"	647	.097	746		401	5650	116	012	.0101	119	119	"	351	42	723
A-874	"	3	"	"	6600	"	"	2629	10	"	65.1	.153	750		484	6821	120	.025	0186	1.34	16.4	"	353	.58	7.41
B-619	"	3	"	"	6613	"	"	270.0	11	"	660	152	745		596	8400	129	039	.0282	1.38	256	"	350	.90	770
			Average - Girder			1 E Bound		262.9			647	.097	746				116					330	351		
						2 "	"	2629			620	.114	7.45	7.07			89					330	350		
						3 "	"	2665			656	.153	750				125					330	353		
						3 W	"	3012			670	.150	735				139					330	355		
A-873	1	3	E	K5A	6529	1560	3010	223.0	2	P	653	.138	677	7.17	5.78	8145	12.2	.034	.0234	140	24.6	330	3.18	.78	7.26

NOTE - The E.U.L.L, Live Load Stress, and Frequencies (Undamped) are computed for the Span acting as a unit

Proportion of Total Load taken by Each Girder is - 1- .788

2- .925

3- 1.232

Sheet 2 Span 36

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat. Defl H Blow D_{N^2} at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens. Net. Sec.			
No.	Series			Class	Eng No.	H. B at 1 R.P.S	Weight (Kips)		No	Kind	at Dist. "P"	Defl. (ins) "D"			R.P.S. "N"	M.P.H.	Dist. "H" (Ft.)	Oscil (ins)				D.L	L.L.	Imp.	Total
							Eng	Tender																	
B-622	1	3	W	L2D	6227	2153	367.0	302.3	84	F	67.6	.157	7.70		1.39	17.14	12.5	.008	.0019	4.21	5.1	3.30	3.62	.19	7.11
A-877	"	1	E	"	6242	"	"	188.2	90	"	61.1	.095	7.31		1.67	20.54	6.0	.007	.0018	3.88	7.6	"	3.44	.26	7.00
B-631	"	2	"	"	"	"	"	"	"	"	60.0	113	7.38		1.67	20.56	4.9	.007	.0022	3.18	6.2	"	3.47	.21	6.98
B-613	"	3	W	"	6246	"	"	185.6	81	"	63.4	.144			1.90	23.36	8.3	.008	.0036	2.50	5.5	"			
B-617	"	3	W	"	6247	"	"	304.8	53	"	62.1	.161	7.89		2.38	29.24	7.0	.013	.0056	2.32	8.1	"	3.71	.30	7.31
B-618	"	3	E	"	6244	"	"	272.1	50	"	62.2	.154	7.55		3.70	45.46	7.1	.016	.0137	1.17	10.4	"	3.55	.37	7.22
B-615	"	3	"	"	6229	"	"	260.1	41	"	64.4	.160	7.89		3.79		9.3	.021	.0144	1.46	13.1	"	3.71	.48	7.49
B-610	"	3	"	"	6247	"	"	251.7	84	"	64.2	.158	7.74		3.89	47.89	9.1	.017	.0151	1.12	10.7	"	3.68	.39	7.37
A-871	"	3	"	"	6228	"	"	259.6	59	"	60.3	.156	7.64		4.15	51.01	5.2	020	.0172	1.16	12.8	"	3.59	.46	7.35
B-614	"	3	"	"	6228	"	"	242.0	64	"	61.3	.156	7.64		4.56	56.08	6.2	.029	.0208	1.39	18.6	"	3.59	.67	7.56
			Average Girder		1	E. Bound		188.2			61.1	.095	7.31	6.94			6.0					3.30	3.44		
					2	" "		"			60.0	.113	7.38				4.9					3.30	3.47		
					3	" "		257.1			62.5	.157	7.70				7.4					3.30	3.62		
					3	W "		264.2			64.4	.154	7.55				9.3					3.30	3.55		
A-870	1	3	E	L2B	6200	1844	364.0	258.0	84	F	63.3	.154	7.55		3.31	40.72	8.2	.012	.0094	1.27	7.8	3.30	3.55	.27	7.12
A-875	"	1	"	"	6205	"	"	283.4	85	"	62.2	.101	7.77		3.85	47.35	7.1	.013	.0083	1.56	13.7	"	3.65	.50	7.45
B-629	"	2	"	"	"	"	"	"	"	"	60.1	.117	7.65		3.87	47.68	5.0	.014	.0101	1.38	12.2	"	3.60	.44	7.37
B-623	"	3	"	"	"	"	"	224.2	51	"	65.7	.153	7.50		4.81	59.19	10.6	.025	.0198	1.26	16.3	"	3.53	.47	7.30
		Average-Girder			1- E. Bound			283.4			62.2	.101	7.77				7.1					3.30	3.65		
					2- "	"		"			60.1	.117	7.65	6.98			5.0					3.30	3.60		
					3- "	"		241.1			64.5	.154	7.50				9.4					3.30	3.53		

TABLE II

DECK PLATE GIRDER SPAN WITH CONCRETE DECK AND BALLASTED TRACK 70 Ft LONG·67'9" c. to C   Sheet 1 Span 37

Test		Girder	Direc of Movement	Locomotive					Cars		Stat L L Defl		E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed		Hammer Blow		Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact 'γ'	Moment Unit Stress (Kips) Tens Net Sec			
No	Series			Class	Eng No.	H B at 1RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist 'P'	Defl (ins) 'D'			R.P.S. 'N'	M.P.H	Dist 'H' (Ft)	Oscil (ins)				D L	L L	Imp	Total
A-867	I	4	W	J1E	6625	1672	3515	300.3	10	P	593	152	760	702	340	4806	62	.012	0089	135	79	330	357	.28	715
B-627	I	4	W	J1D	6617	1691	3530	3012	11	P	64.8	.157	7.85		286	4036	117	.009	.0064	141	57	330	369	.21	7.20
B-625	-	4	-	-	6607	1691	353.0	301.2	13	P	61.6	.151	755		299	4211	85	010	0070	143	66	330	355	.23	708
A-865	-	4	-	..	6613	1691	353.0	297.3	12	P	655	.148	740		3.05	4237	124	008	0073	1.10	54	330	348	19	697
			Average-Girder 4- W Bound					299.9			64.0	.152	7.60	7.02			109					3.30	357		
B-626	1	4	W	L2D	6244	2153	367.0	302.3	68	F	637	.154	770		2.04	2513	86	.007	0041	171	45	3.30	362	.16	708
B-628	-	4	-	..	6243	..	..	2627	105	-	660	.154	770		220	2710	109	009	.0047	191	58	..	..	.20	712
A-868	..	4	..	-	6228	..	-	3048	65	..	694	.156	780		303	3732	143	018	.0072	250	115	..	367	.42	739
			Average Girder 4- W Bound					289.9			664	155	775	700			113					330	364		
A-866	I	4	W	L2B	6205	1844	364.0	2845	46	F	665	.146	7.30		1.66	2044	114	.009	0023	3.91	62	330	343	.21	6.94
B-624	-	4	-	..	..	-	-	287.0	79	..	65.4	.146	730		256	3147	103	.009	.0055	164	62	..	343	.21	694
			Average Girder 4- W. Bound					285.8			66.0	.146	7.30	7.10			10.9					3.30	3.43		

NOTE:- The E.U.LL, Live Load Stress and Frequencies (undamped) are computed for the span acting as a unit. The distribution of the Load taken by the girders should be the same as Span Nº 36. That is - Girder 4 1.232

5 .926

6 .788

SPAN NO. 38

A deck girder with a concrete deck and ballasted track. Length over all 52 ft.; center to center of bearings 50 ft. 4 in. There are five odd girders in this span, the lightest girders being on the inside, which increases the eccentricity of the loading. See Fig. 88.

Measurements were taken on the inside girder (No. 5) only, so that we have no definite information as to the deflection of the other beams. On span 39, which is of the same length, the deflection factor was found to be 1.25. Assuming the same value for this bridge, we find that the deflection of the inside girder is 1.60 times the average deflection of the group. In the other spans the inner girder has taken about 1.25 of the average load, but the high proportion found for this span can be accounted for by the larger eccentricity, the lighter girders being under the load. The error can not be great as the E.U.L.L., as determined from the corrected average deflection, checks very closely.

It is impossible to determine the damping factor for this span. Its loaded frequency is greater than 9, so that synchronous speeds are impossible. The oscillations have been plotted in Fig. 89. It will be seen that at about 5 r.p.s., they are a maximum with some magnification, after which they become smaller. This magnification, at half synchronous speed, was found, it may be remembered, in most of the longer spans having open decks.

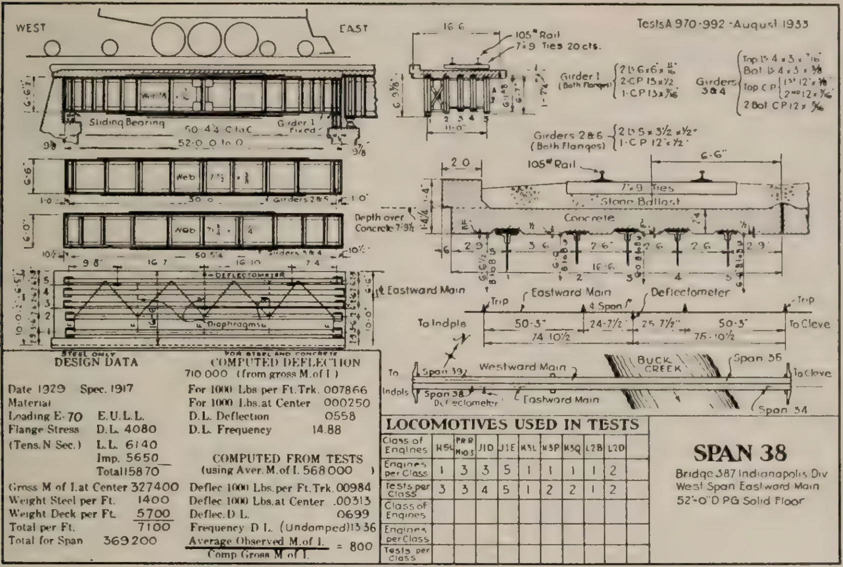
This span, due to the concrete deck, is so stiff and the amount of damping is so high, that at a speed of 7 r.p.s. the dynamic magnifier would be unity or less, and such spans may be considered as short spans, in which the hammer blow acts as a static force, without magnification.

SPAN NO. 39

A deck girder, with a concrete deck carrying a ballasted track. Length over all 52 ft.; center to center of bearing 50 ft. 4 in. There are three girders in this span. See Fig. 90.

Most of the measurements were taken on the inside (3) girder, but a few were taken on the outside (1) and center (2) girders. From these readings, it was found that the inside girder takes 1.248 of the average load, and the deflection factor was found to be 1.25. This girder, like span 38, is very stiff, the loaded frequency being about 9.5. Synchronous speeds are impossible, so that the damping factor cannot be determined.

The oscillations have been plotted and are shown in Fig. 91. As in span 38, the maximum values are found at about one-half synchronous speed, after which they become smaller.



DESIGN DATA

Date 1929 Spec. 1917
Material
Loading E-70 E.U.L.L.
Flange Stress D.L. 4080
(Tens. N Sec.) L.L. 6140
Imp. 5650
Total 15870
Gross M of I. at Center 327400
Weight Steel per Ft. 1400
Weight Deck per Ft. 5700
Total per Ft. 7100
Total for Span 369200

COMPUTED DEFLECTION
710 000 (from gross M. of I.)
For 1000 Lbs per Ft. Trk. 007866
For 1000 Lbs. at Center 000250
D.L. Deflection 0558
D.L. Frequency 14.88

COMPUTED FROM TESTS
(using Aver. M. of I. 568 000)
Deflec 1000 Lbs. per Ft. Trk. 00984
Deflec 1000 Lbs. at Center .00313
Deflec. D.L. 0699
Frequency D.L. (Undamped) 13 36

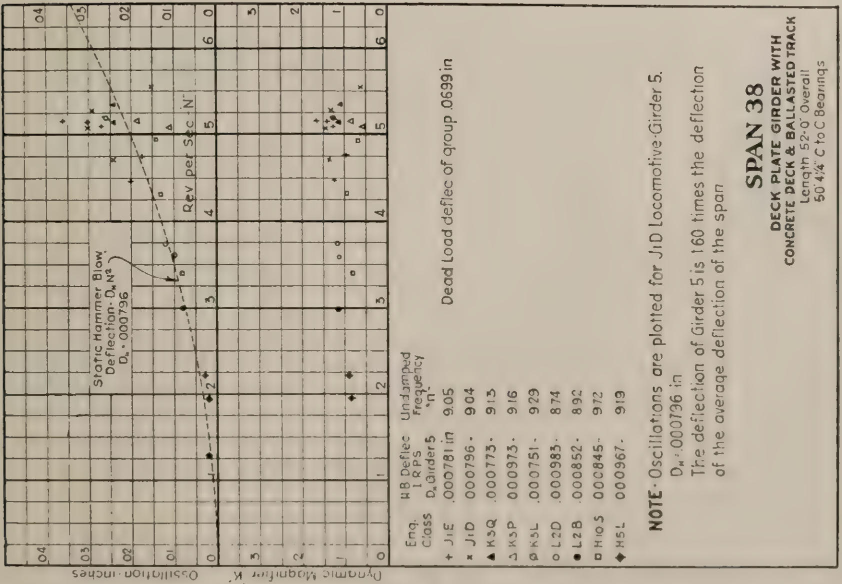
$\frac{\text{Average Observed M. of I.}}{\text{Comp Gross M of I.}} = 800$

LOCOMOTIVES USED IN TESTS

Class of Engines	H5L	PRR H10S	J1D	J1E	K3L	K3P	K3Q	L2B	L2D	
Engines per Class	1	3	3	5	1	1	1	1	2	
Tests per Class	3	3	4	5	1	2	2	1	2	
Class of Engines										
Engines per Class										
Tests per Class										

SPAN 38
Bridge 387 Indianapolis Div
West Span Eastward Main
52'-0"D PG Solid Floor

Fig. 88



Eng. Class	HB Deflec 1 RPS D_x Girder 5	Undamped Frequency 'n'
+ J1E	.000781 in	9.05
× J1D	.000796 -	9.04
▲ K3Q	.000773 -	9.13
△ K3P	.000973 -	9.16
⊘ K3L	.000751 -	9.29
○ L2D	.000983 -	8.74
● L2B	.000852 -	8.92
□ H10S	.000845 -	9.72
◆ H5L	.000967 -	9.19

NOTE - Oscillations are plotted for J1D Locomotive - Girder 5.
D_x = .000796 in
The deflection of Girder 5 is 1.60 times the deflection of the average deflection of the span

SPAN 38
DECK PLATE GIRDER WITH CONCRETE DECK & BALLASTED TRACK
Length 52'-0" Overall
50'4¼" C to C Bearings

Fig. 89

TABLE LII

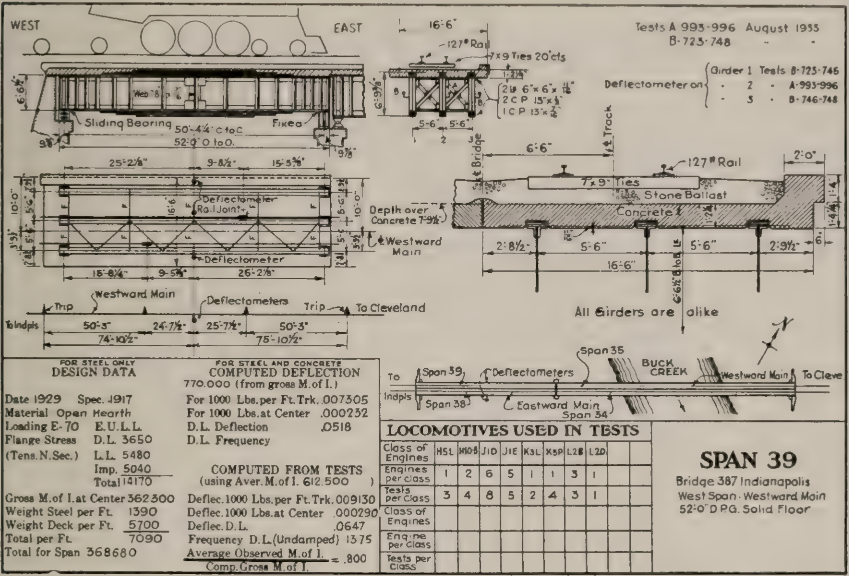
DECK PLATE GIRDER-WITH CONCRETE DECK AND BALLASTED TRACK-LENGTH-52 Ft. C to C. 50'-4¼" Sheet 1 Span 38

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1RPS	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist. "P"	Stat L L Defl Defl. (ins) "D"	E.U.L.L. (Kips)	Loaded Frequency 'n'	Speed R.P.S "N"	Speed M.P.H.	Hammer Blow Dist "H" (Ft.)	Hammer Blow Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens. Net Sec D.L	L L	Imp.	Total
A-984	1	5	E	J1E	6628	1672	351.5	302.4	8	P	50.0	.121	7.68		4.48	63.10	5.6	.020	.0157	1.27	16.8	3.12	3.38	.57	7.07
A-977	"	"	"	"	6626	"	"	"	12	"	50.0	.125	7.94		4.76	67.15	5.6	.017	.0177	.96	14.2	"	3.49	.50	7.11
A-978	"	"	"	"	6620	"	"	"	8	"	48.6	.124	7.87		5.09	71.80	4.2	.026	.0203	1.28	20.9	"	3.46	.72	7.30
A-970	"	"	"	"	6627	"	"	"	9	"	48.7	.124	7.87		5.14	72.43	4.3	.029	.0207	1.40	24.4	"	3.46	.84	7.42
A-971	"	"	"	"	6624	"	"	"	8	"	49.1	.125	7.94		5.15	72.63	4.7	.035	.0208	1.68	28.0	"	3.49	.98	7.59
				Average Girder 4			351.5	302.4			49.3	.124	7.87	9.05			4.9					3.12	3.46		
A-991	1	5	E	J1D	6610	1691	353.0	303.0	9	P	43.5	.128	8.09		4.71	66.37	0.9	.024	.0178	1.35	18.7	3.12	3.57	.67	7.36
A-985	"	"	"	"	6610	"	"	"	8	"	45.0	.120	7.62		5.07	71.44	0.6	.030	.0207	1.45	24.3	"	3.35	.81	7.28
A-992	"	"	"	"	6618	"	"	"	8	"	48.0	.120	7.62		5.27	74.23	3.6	.029	.0222	1.31	24.3	"	3.35	.81	7.28
A-973	"	"	"	"	6602	"	"	"	4	"	49.2	.121	7.68		5.54	78.08	4.8	.015	.0245	.61	12.4	"	3.38	.42	6.92
				Average Girder 4			353.0	303.0			46.7	.122	7.75	9.04			2.3					3.12	3.40		
A-989	1	5	E	K3Q	6495	1650	295.5	209.6	5	P	49.5	.119	7.56		5.14	72.40	5.7	.024	.0205	1.17	20.2	3.12	3.32	.67	7.11
A-982	"	"	"	"	6495	"	"	"	5	"	44.6	.116	7.37		5.36	75.53	0.8	.024	.0223	1.08	20.7	"	3.24	.67	7.03
				Average Girder 4			295.5	209.6			47.5	.118	7.49	9.13			3.7					3.12	3.28		
A-975	1	5	E	K3P-I	6479	2076	280.2	209.6	7	P	47.5	.109	6.92		5.09	71.80	3.7	.014	.0253	.58	11.8	3.12	3.04	.36	6.52
A-986	"	"	"	"	6479	"	"	"	5	"	47.0	.113	7.18		5.15	72.62	3.2	.022	.0259	.85	19.3	"	3.15	.61	6.87
				Average Girder 4			280.2	209.6			47.3	.111	7.05	9.16			3.5					3.12	3.09		
A-979	1	5	E	K3L	6474	1603	274.0	209.0	7	P	46.6	.108	6.86	9.29	5.19	73.15	2.8	.025	.0203	1.23	22.7	3.12	3.01	.68	6.81

Sheet 2 Span 38

Test No	Test Series	Girder	Direc of Movement	Locomotive Class	Locomotive Eng No.	Locomotive H B at 1RPS	Locomotive Weight (Kips) Eng	Locomotive Weight (Kips) Tender	Cars No	Cars Kind	Stat L L Defl at Dist "P"	Stat L L Defl Defl (ins) D	E.U.L.L (Kips)	Loaded Frequency 'n'	Speed R.P.S "N"	Speed M.P.H	Hammer Blow Dist "H" (Ft)	Hammer Blow Oscil (ins)	Stat Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier 'K'	Impact %	Moment Unit Stress (Kips) Tens Net Sec DL	L L	Imp	Total
A-980	1	5	E	L2D	6238	2153	367.0	309.6	54	F	45.8	.136	8.64		3.58	44.07	-1.5	.013	.0116	1.12	9.6	3.12	3.79	.36	7.27
A-972	"	"	"	"	6239	"	"	"	51	"	47.6	.140	8.89		3.75	46.18	0.3	.015	.0128	1.17	10.7	"	3.90	.42	7.44
				Average Girder 4			367.0	309.6			46.7	.138	8.76	8.74			-0.6					3.12	3.85		
A-987	1	5	E	L2B	6211	1844	364.0	292.3	68	F	49.7	.129	8.19	8.92	2.99		2.4	.009	.0077	1.17	7.0	3.12	3.60	.25	6.97
A-988	1	5	E	H5L-I	6035	2090	275.7	150.5	20	F	47.4	.113	7.18		1.30	14.61	5.0	.003	.0016	1.87	2.6	3.12	3.15	.08	6.35
A-974	"	"	"	"	6035	"	"	"	6	"	48.4				1.96	22.03	6.0	.003	.0036	.84		"			
A-981	"	"	"	"	6035	"	"	"	5	"	48.4	.115	7.30		2.23	25.02	6.0	.004	.0046	.88	3.5	"	3.21	.11	6.44
				Average Girder 4			275.7	150.5			48.1	.114	7.24	9.19			5.7					3.12	3.18		
A-990	1	5	E	Penn. H10S	8594	1830	247.5	176.5	7	F	39.5	.098	6.24		3.40	37.77		.008	.0099	.79	8.2	3.12	2.73	.22	6.07
A-976	"	"	"	"	8851	"	"	"	8	"	49.5	.081	5.34		4.32	47.77	7.1	.013	.0138	.94	16.0	"	2.26	.36	5.74
A-983	"	"	"	"	8811	"	"	"	12	"	49.8	.089	5.65		4.93	54.56	7.4	.014	.0206	.68	15.7	"	2.48	.39	5.99
				Average Girder 4			247.5	176.5				.090	5.72	9.72								3.12	2.50		

NOTE:- E.U.L.L., Frequencies and LL Stresses are the average for the span - Deflections in Girder 5 are 1.60 times the average



Tests A 993-996 August 1933
B-723-748 " "

Deflectometer on Girder 1 Tests B-723-745
" 2 " A-993-996
" 3 " B-746-748

FOR STEEL ONLY
DESIGN DATA

Date 1929	Spec. 1917
Material	Open Hearth
Loading E-70	E.U.L.L.
Flange Stress	D.L. 3650
(Tens. N. Sec.)	L.L. 5480
	Imp. 5040
	Total 14170
Gross M. of I. at Center	362300
Weight Steel per Ft.	1390
Weight Deck per Ft.	5700
Total per Ft.	7090
Total for Span	368680

FOR STEEL AND CONCRETE
COMPUTED DEFLECTION
770.000 (from gross M. of I.)

For 1000 Lbs. per Ft. Trk.	.007305
For 1000 Lbs. at Center	.000232
D.L. Deflection	.0518
D.L. Frequency	

COMPUTED FROM TESTS
(using Aver. M. of I. 612.500)

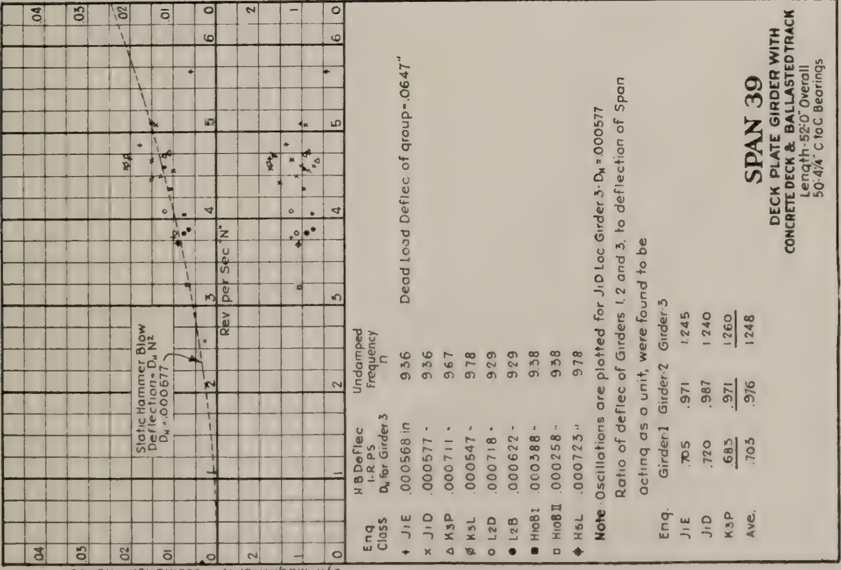
Deflec. 1000 Lbs. per Ft. Trk.	.009130
Deflec. 1000 Lbs. at Center	.000290
Deflec. D.L.	.0647
Frequency D.L. (Undamped)	1375
Average Observed M. of I. / Comp. Gross M. of I.	= .800

LOCOMOTIVES USED IN TESTS

Class of Engines	H5L	H10-B	J1D	J1E	K3L	K3P	L2B	L2D		
Engines per class	1	2	6	5	1	1	3	1		
Tests per Class	3	4	8	5	2	4	3	1		
Class of Engines										
Engine per Class										
Tests per Class										

SPAN 39
Bridge 387 Indianapolis
West Span - Westward Main
52'-0" D P.G. Solid Floor

Fig. 90



Eng Class	H B Deflec 1-R P S D_H for Girder 3	Undamped Frequency n
+ J1E	.000568 in	936
× J1D	.000577 "	936
△ K3P	.000711 "	967
∅ K5L	.000547 "	978
○ L2D	.000718 "	929
● L2B	.000622 "	929
■ H10B I	.000388 "	938
□ H10B II	.000258 "	938
◆ H5L	.000723 "	978

Dead Load Deflec of group = .0647"

Note Oscillations are plotted for J1D Loc Girder 3 - D_H = .000577

Ratio of deflec of Girders 1, 2 and 3, to deflection of Span acting as a unit, were found to be

Eng.	Girder-1	Girder-2	Girder-3
J1E	.705	.971	1.245
J1D	.720	.987	1.240
K3P	.683	.971	1.260
Ave.	.703	.976	1.248

SPAN 39
DECK PLATE GIRDER WITH
CONCRETE DECK & BALLASTED TRACK
Length - 52'-0" Overall
50'-4¼" C to C Bearings

Fig. 91

TABLE LIII

DECK PLATE GIRDER SPAN WITH CONCRETE AND BALLASTED TRACK-LENGTH 52'-0" 50'-4¼" C to C

Sheet 1 Span 39

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens. Net Sec			
No	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1 RPS.	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) "D"	E U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D.L	L.L	Imp	Total
B-725	1	3	W	J1E	6622	1672	3516	302.4	7	P	456	.093	8.16		3.78	5329	1.2	.010	.0081	123	108	282	324	35	641
B-740	〃	3	〃	〃	6628	〃	〃	〃	12	〃	502	.094	824		4.69	66.12	5.8	.020	.0122	164	213	〃	3.27	.70	679
B-741	〃	3	〃	〃	6626	〃	〃	〃	10	〃	49.5	.088	7.72		485	68.40	5.1	.018	.0133	1.36	20.4	〃	3.06	62	650
B-735	〃	3	〃	〃	6624	〃	〃	〃	9	〃	50.2	.094	8.24		5.09	71.72	5.8	.015	.0147	1.02	16.0	〃	3.27	.52	6.61
A-993	〃	3	〃	〃	6620	〃	〃	〃	11	〃	47.0	.073	8.20		5.69	80.17	26	.006	.0143	.42	8.2	〃	333	27	6.42
				Average	Girder	3	351.5	302.4			489	.092	8.07	9.36			45					282	3.20		
						2	351.5	3024			47.0	.073	8.20				26					282	333		
B-733	1	3	W	J1D	6611	1691	353.0	303.0	12	P	48.0	.093	8.16		4.41	6219	36	.015	0099	1.51	161	282	3.24	.62	6.58
B-739	〃	3	〃	〃	6613	〃	〃	〃	9	〃	49.1	.093	816		449	63.27	47	013	.0116	1.12	14.0	〃	324	45	651
B-731	〃	3	〃	〃	6610	〃	〃	〃	11	〃	498	.088	772		4.54	64.0	5.4	.010	.0119	84	11.4	〃	3.06	.35	6.23
B-726	〃	3	〃	〃	6607	〃	〃	〃	11	〃	47.5	.093	8.16		458	64.57	21	.021	0121	173	22.6	〃	324	.73	679
A-994	〃	2	〃	〃	6617	〃	〃	〃	10	〃	49.2	.074	831		4.60	6483	4.8	.007	.0097	.72	95	〃	337	.32	651
B-746	〃	1	〃	〃	〃	〃	〃	〃	〃	〃	50.0	.054	8.59		461	6500	56	.007	.0071	100	13.0	〃	3.34	.43	6.59
B-745	〃	3	〃	〃	6607	〃	〃	〃	9	〃	492	.090	789		468	6603	48	015	0122	123	167	〃	3.13	.52	647
B-727	〃	3	〃	〃	6600	〃	〃	〃	9	〃	45.6	.093	816		5.07	7144	12	014	0148	.95	15.1	〃	324	.49	6.55
				Average	Girder	1	3530	303.0			50.0	.054	859	9.36			5.6					282	334		
					〃	2	353.0	303.0			492	.074	8.31				4.8					282	337		
					〃	3	353.0	303.0			48.2	.092	806				38					2.82	321		
B-743	1	3	W	K3L	6474	1603	274 0	209.0	4	P	42.4	.074	6.73		4.61	6499	-06	.020	.0116	1.78	270	282	268	.73	623
B-728	〃	3	〃	〃	6474	〃	〃	〃	6	〃	45.4	.084	7.37		473	6674	16	.020	.0122	164	238	〃	292	.69	643
				Average Girder		3	2740	209.0			439	.079	6.93	978			-01					282	275		

NOTE:- E.U.L.L, Frequencies and L.L Stresses are average for group of beams

Sheet 2 Span 39

Test				Locomotive					Cars		Stat L L Defl				Speed		Hammer Blow					Moment Unit Stress (Kips) Tens Net Sec			
No.	Series	Girder	Direc of Movement	Class	Eng No.	H B at 1 RPS	Weight (Kips) Eng	Weight (Kips) Tender	No	Kind	at Dist "P"	Defl (ins) D	E U.L.L. (Kips)	Loaded Frequency "n"	R.P.S. "N"	M.P.H	Dist "H" (Ft)	Oscil (ins)	Stat. Defl H Blow $D_H N^2$ at Center	Dynamic Magnifier "K"	Impact %	D L	L L	Imp	Total
B-748	1	1	W	K3P-I	6479	2076	2802	209.6	4	P	48.3	.045	7.03		465	65.50	45	.005	.0084	.60	11.1	2.82	2.79	.31	592
A-996	〃	2	〃	〃	〃	〃	〃	〃	〃	〃	443	.064	703		465	65.50	0.5	.007	0119	.59	109	〃	292	.32	606
B-723	〃	3	〃	〃	6479	〃	〃	〃	5	〃	445	.084	737		473	66.74	07	015	.0159	.94	178	〃	292	.52	626
B-737	〃	3	〃	〃	6479	〃	〃	〃	4	〃	496	.083	7.27		4.75	6694	58	.014	.0161	.87	169	〃	289	48	619
				Average	Girder	1	280.2	209.6			483	.045	703	9.67			45					282	279		
						2	280.2	2096			443	.064	703				05					282	292		
						3	280.2	209.6			470	.083	7.27				32					2.82	289		
B-729	1	3	W	L2D	6238	2153	3670	309.6	49	F	497	.096	8.42	929	3.83	47.15	24	.012	.0105	114	12.5	2.82	3.36	.42	660
B-744	1	3	W	L2B	6212	1844	364.0	292.3	70	F	46.3	.098	8.59		3.84	4723	-10	.008	.0091	.89	81	282	331	.26	639
B-724	〃	3	〃	〃	6209	〃	〃	〃	72	〃	490	.096	842		3.88	4779	1.7	.007	.0093	.75	7.3	〃	336	.25	643
B-738	〃	3	〃	〃	6217	〃	〃	〃	72	〃	466	.094	824		409	5037	-0.7	.013	.0103	126	13.8	〃	327	.45	654
				Average	Girder	3	364.0	2923			47.3	.096	8.42	929			0					2.82	3.36		
B-732	1	3	W	H10B-II	360	803	334.5	2760	96	F	475	094	824		321	3607	6.3	003	.0026	110	63	282	327	.21	630
B-742	〃	3	〃	〃	222	1188	〃	〃	30	〃	47.8	.093	815		405	45.55	75	.005	.0064	.78	5.4	〃	3.24	.17	623
B-730	〃	3	〃	〃	222	〃	〃	〃	28	〃	45.0	.092	807		435	4894	47	.007	.0073	.96	7.6	〃	320	.24	626
B-736	〃	3	〃	〃	222	〃	〃	〃	29	〃	46.5	.091	798		460	5166	62	.008	.0082	.98	88	〃	317	.28	617
				Average	Girder	3	334.5	2760			467	.093	815	938			64					282	3.24		
B-747	1	1	W	H5·L·I	6035	2090	2757	150.5	2	F	44.3	.038	594		215	2417	19	.002	.0016	125	79	282	2.35	.18	535
A-995	〃	2	〃	〃	〃	〃	〃	〃	〃	〃	420	.059	662		215	2418	-04	004	.0026	154	69	〃	269	.19	5.70
B-734	〃	3	〃	〃	603	〃	〃	〃	6	〃	466	081	710		372	42.04	22	.011	.0100	110	136	〃	2.82	38	6.02
														978											

Appendix C

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DISCUSSIONS

DISCUSSION ON STANDARDIZATION

(For Report, see pp. 206–217)

Mr. E. M. Hastings (Richmond, Fredericksburg & Potomac):—The report is found in Bulletin 382, beginning at page 205. This Committee on Standardization is not a committee that presents subject-matter for approval and publication in the Manual. It is a committee which is charged with the duty of presenting information to the Association.

If we may be permitted, we will present the report in reverse order.

Subject (3) is to "Maintain contact with standardization bodies and keep the Association informed on important matters developed by such contact." This is a progress report. You will find in Appendix C the American Standards Association technical projects on which the Association of American Railroads is now cooperating, giving the names of members representing the railway associations; as Appendix B, the standards approved by the American Standards Association in the period September 1, 1934 to September 1, 1935. You will find in the text of the report some very interesting information on the activities of the American Standards Association, and a brief report of the activities of the Canadian Engineering Standards Association, which has been furnished your Committee by B. Stuart McKenzie, Secretary of the CESA.

You will also find reference to the cooperative or contact work with the American Society for Testing Materials, and may I say at this point that I feel your Committee and the American Railway Engineering Association has made distinct progress during the year that has just closed in cooperative work with the American Society for Testing Materials, and many of your standing committees are now represented on the standing committees of the ASTM.

On Subject (2), "What AREA recommended practices should be sponsored as projects for National Standardization," we briefly say that the Committee reports progress. It does not present at this time any such projects for national standardization.

Under Subject (1), "What AREA recommended practices should be advocated for general use on railroads," a tabulation is given of the specifications and recommended practices that have been adopted by the Association which are now contained in the Manual and the supplements thereto. You will find that in the report as Appendix A.

Your Committee on Standardization is composed of the Chairmen of all of your standing committees. This tabulation has been made up as a result of the study of the chairmen of those committees, and I am asking the membership of this Association to not pass this tabulation up as just another few pages of printed matter. It is worthy of your careful consideration and it is worthy of your bringing to the attention of the officers managing your several railroads.

The Manual of this Association is not a burial-ground. The work of the committees of this Association in the past 37 years has found its way into a volume after having been given the most careful consideration not only by Committees, but by the convention and the membership as a whole. That volume should not be a burial-ground. It should have erected over it a tombstone that bears an inscription more worthy of the volume than the inscription I saw on a tombstone in old Virginia some years ago in one of the ancient burial-grounds there, which read sort of this way, if I can remember it correctly:

"Underneath these cold gray stones,
Lies all that is left of Susan Jones.
Her name was Smith, and was not Jones,
But Jones was used to rhyme with stones."

The Manual is not a volume that has been set up as purposeless as might that stone be considered. I have been particularly interested in the work of the young men in recent years. I think all of us as we become older become more interested in the work of young men. I want to thank you for the reference that you made in your address this morning to those young men who are now getting their education in our great colleges and universities. Just recently I was addressing a group of students, members of a student chapter of the American Society of Civil Engineers. One of those young men asked me, "What is the future for a young man in the railroad service?" I tried to answer him in as glowing terms as I could. He asked me particularly about the work of the American Railway Engineering Association. He said that he was very much interested in their publications that came to their reading room. He said further that he was much interested in the recommended practices that were found in the Manual of that Association and he asked me the extent to which they were used. I will not dwell at length upon the answer which I gave him.

I have said all of that this morning, gentlemen, to impress upon you what I feel and I think what your Committee on Standardization feels is the thing that you should do, and that is to give careful consideration to this tabulation in Appendix A and help your Committee to bring it more and more up to date as the years go by and possibly help your Committee get out from the tabulation some things which should be pushed forward more generally and for more uniform use.

I think I heard it said, in fact, I know I heard it said on an occasion not so long ago that the extent to which a man was loyal was a measure of his loyalty, the extent to which he was faithful was a measure of his faith. I should like to extend that just a step further and say that the extent to which we adhere and follow the recommended practices of the American Railway Engineering Association is the extent to which the work of that Association is of value to us individually and to our respective railroads.

This completes the report of the Committee.

The President:—Thank you, Mr. Hastings. The Committee is excused with the thanks of the convention (Applause).

DISCUSSION ON ROADWAY

(For Report, see pp. 113–155)

Mr. Geo. S. Fanning (Erie):—You will find the report of the Committee on Roadway in Bulletin 381, beginning on page 113. This Committee has, during the past year, experimented with a new organization. We have divided the field of work of the Committee into nine general sub-divisions. We have a standing sub-committee on each of these. You will find on page 114 and from there on an outline of the entire field of work of this Committee which we will henceforth try to follow. We have no special Committee on Revision of the Manual. The Committee handling any particular subject handles also the revision of the Manual on that subject; so such revisions will be reported by the Sub-Committee Chairmen as they follow through.

Our first sub-division is on "Physical Properties of Earth Materials." You will find a progress report beginning on page 118. This serves as an introduction to further reports in the development of the comprehensive outline given in Appendix A. It considers in a general way the nature of the materials with which Engineers have to deal for the support of tracks and structures. The report indicates the physical properties that determine the behavior of roadbed and foundation soils. It briefly reviews the various systems of soil classification which, by means of field and laboratory tests, constitute a new scientific approach to the attainment of effective stability. The report is offered as information.

Our second subject is on "Natural Waterways." The report on that is found in Appendix C and will be offered by the Sub-Committee Chairman, Mr. Bayer.

Mr. E. J. Bayer (Peoria & Eastern):—The Sub-Committee on Natural Waterways reports some progress and recommends that the definitions be withdrawn from the Manual with the idea that they will be revised during the coming year. That applies particularly to "Material on Waterways" on pages 38, 39 and 40. The Committee recommends that they be withdrawn.

Chairman Geo. S. Fanning:—I so move.

(The motion was regularly seconded, was put to a vote and carried.)

The third subject is "Service Life of Culverts," on which we are bringing in a final report which will be read by Mr. A. E. Botts, Vice-Chairman of the Committee and Chairman of this Sub-Committee.

Mr. A. E. Botts (Chesapeake & Ohio):—The report of Sub-Committee 3 is found in Bulletin 381, pages 123 to 132 inclusive. This subject was carried over from last year, a report on which is contained in Vol. 36, pages 318 to 325. The only change in this year's report over last year's report is the separation under "Masonry" of concrete culverts from brick and stone culverts. This year's report includes all culverts inspected as contained in last year's report. A total of more than 10,000 culverts have been inspected. May I say that the expected life reflected by this report is more accurate than that reflected in last year's report due to the great number of culverts inspected and the wide field in which the information was secured and we suggest that the conclusions on page 125 be referred to as a guide in selecting the proper type of culvert.

The report is offered as information.

The second subject is shown under Appendix E, Specifications for Cast Iron Culvert Pipe. Last year the Roadway Committee, in Vol. 36, page 316, reported that the cast iron culvert pipe AREA specifications were not used on many railroads. Your Committee undertook an investigation and have summarized our results as to the cost of various sizes of cast iron pipe made under specifications of the AREA, AWWA and ASTM. The result is the tabulation on page 127.

The report at the top of page 128 directs attention to the fact that pipe made to ASTM specifications of a grade equal to or heavier than that of AREA specifications is uniformly lower in cost except for the 12-inch size.

With the information we recommend withdrawing of AREA specifications, shown in Bulletin 327, pages 6 and 7, from the Manual and recommend the use of ASTM Tentative Specification A 142–34T.

The President:—You have heard the report of the Committee and the motion is on the acceptance of its recommendations.

(The question was put to a vote and carried.)

Mr. B. R. Leffler (New York Central):—I do not know whether I am in order but I want to find out if it is in order to discuss the conclusions on page 125 regarding the service life of culverts.

The President:—Certainly. If you have any constructive contributions, the convention will be glad to have them.

Mr. B. R. Leffler:—I notice the recommendation gives a service life of corrugated metal pipe of 33 years. It seems to me that is rather optimistic. In fact, this pipe has not been made probably further back than 20 years. This kind of pipe has been subject to considerable discussion among Engineers for the last 10 or 15 years. I think that the best conclusion should be for not more than 15 years.

In the same way, concrete pipe has not been used for 67 years, and there has been a lot of poor concrete pipe made as well as some good concrete pipe. That, I think, should be cut down about half.

So far as vitrified clay pipe is concerned, in my experience I have seen plenty of vitrified clay culverts go to pieces, not because of deterioration of the quality of the pipe but because of frost action and overload. I think that that will determine the life of vitrified clay more than the deterioration of quality of material.

The rest of the conclusions, I think, are fairly good except that I am not quite sure that concrete culverts will last 92 years. I am quite sure there are a good many of them that will not last a quarter of that time.

I do not know how the Committee reached those conclusions, but it appears to me that it was a projection into the future from some basing data. I have always been a poor prophet; that is, when it comes to telling something that is going to happen sixty or seventy years from now. I think I would make a complete failure.

I have no motion to make because I have not discussed this subject with anybody, but I am looking with very skeptical eyes on the conclusions.

Mr. C. W. Baldridge (Atchison, Topeka & Santa Fe):—No chance was given for discussion on this subject, therefore I am breaking in. Also I note on page 124, about the fourth paragraph, I believe it is, the report states "there were 1676 corrugated metal culverts inspected with an average age of 14.84 years." I am curious to know whether or not the average life of the culvert is to be based on the number of culverts in service at the present time, the average life of which is already 14 years. If that is the case, then all failures that may have occurred prior to this particular time, the very failures that would reduce the average life to the greatest extent, are excluded from your calculations.

I do not believe that the process used by this Committee will quite give us a correct figure for the average life of culverts.

Mr. A. E. Botts:—The Committee secured this information, as stated in last year's report, from questionnaires, or rather a form which was sent to the various railroads to be filled out. In this form were all the features of culverts that we could have included. The culverts had a thorough inspection, and the individual person inspecting has to enter into each case. Each culvert inspected was given a rating. In other words, if it were thought to be 75 per cent good out of 100 per cent perfect, it was given a rating like that. Of course, that is the basis on which all of this data has been assembled and shown in these reports.

Whether there is some other method which would be more desirable, the Committee is not in position to say, but I do believe that this method we have used is thorough, and it seems to have taken into consideration every feature that goes into the make-up of culverts, except it does not attempt to deal with the materials in the culverts. In other words, we did not go so far as to analyze any method to see whether it was one kind or another, and we did not get the chemical analyses. I might say that that particular feature was not included in this list. It was simply from a field inspection of the culverts as they were found by practical men assigned to those duties by the various railroads, and this is the correct answer to the problem as it was sent to us.

We make a few remarks about the expected life of each type of culvert on pages 124 and 125, but I do not see any use in reading them.

There is a further comment as to the 14 years average life of corrugated metal pipe, resulting in an expected life of 33 years. We realize that very few concrete culverts, or we know that very probably none have an age that we anticipate here for concrete pipe. I am not sure that there is a corrugated metal pipe in existence as old as we have shown here. It is probable that cast iron pipes have those ages. That is not the basis on which this line-up is figured. It is the expected life. Of course, you certainly can go out and inspect a culvert or any other railway structure or building and have some practical idea of what its rating is as compared to something new. That is the basis. We spent quite a little time on this subject before we arrived at some method to get a uniform report from the various railroads. If anybody can furnish a more desirable method of getting this information, the Committee would be very glad to accept it.

Mr. B. R. Leffler:—I do not like to see a prediction put before the convention as a conclusion. This Association generally sticks to concrete facts, and my objection to those conclusions, so-called, lies in the fact that they are nothing but predictions and they are subject to all the uncertainties that any prediction can be subject to. They will be used in time to come by some bureau, probably a governmental bureau, which will come around and say, "Why, your own Association says you can get 33 years out of a tin pipe." We will be asked, "Why use a concrete culvert or why use a cast iron culvert when you can get 33 years out of a tin pipe?"

I do not think that we will want to go on record in endorsing any prediction. This prediction, as I look at it, is just an opinion of a lot of Engineers. Well and good, but that is all it should be taken for.

Chairman Geo. S. Fanning:—May I say a word about the value of these conclusions? I do not believe that any of us using corrugated metal pipe culverts believe that all of them are going to last 33 years. Of the 1676 that were inspected by the inspectors for us, they found, based on the formula which was used for all types of culverts, that that particular group would have an average life of 33 years.

It seems to me that the lives given here are more relative than absolute; we think an Engineer can draw from this that a concrete pipe is going to last twice as long as a corrugated pipe. I think from that point of view this information will be found useful. It bears out the opinion many Engineers have had, that more substantial structures are well worth their extra cost in the extra life that can be gotten from them.

If you will consider these lives on a relative basis rather than on an absolute basis, I think you will find some use for this information.

The President:—The question under discussion relates to the service life of concrete culverts. Mr. Leffler's interrogations apparently refer to metal culverts.

Mr. J. E. Willoughby (Atlantic Coast Line):—The Committee puts the Association on record as to what service life may be expected. Those of us who have used corrugated metal pipe know that corrugated metal pipe will not last 33 years on an average.

Mr. Edwin F. Wendt (Consulting Engineer):—The Bell Telephone Company has made extensive scientific investigations in connection with the life of materials. The telephone industry is only about 50 years old. Mr. Leffler has the right idea that if a scientific determination is to be made of the life of materials it is necessary to have extensive data.

The Consulting Engineer for the Bell Telephone Company appeared before the Interstate Commerce Commission in connection with its investigation of depreciation and testified that it will be many years before sufficient data is collected on which any scientific determination can be made as to the life of many items of material in a telephone plant. There were, he said, a number of items and groups of items on which scientific judgment could be rendered, but he warned his hearers not to jump at conclusions. It is one thing to guess at the life of materials for the purpose of making charges on the books; it is another thing to make a scientific determination.

It seems to me that it will be many years before there is sufficient data on which to make a scientific decision as to the life of hundreds of items of material in the railway plant. It is, however, possible to make guesses, and some of the guesses may be pretty good. However, Mr. Leffler has concentrated on a point which needs to be carefully considered, and that is, when we make a scientific investigation we must have a large amount of data as a basis for an intelligent determination.

The President:—Are there any further remarks?

Mr. W. J. Burton (Missouri Pacific):—I think Mr. Baldridge made an important point that I do not believe has been answered by the Committee. This is the question as to disregarding the lives of the culverts which had already passed out of existence at the time of the investigation. It seems to me that unless these culverts are taken into account the figures must be wrong.

Mr. A. E. Botts:—The only answer to that is that you give a rating after you have made a thorough inspection of some particular culvert. You give a rating and you have taken into consideration the life it has passed.

Mr. W. J. Burton:—I think you misunderstood. There are certain culverts which had failed and had been taken out of service at the time of the investigation. I think this is the point Mr. Baldridge had in mind. Unless the results secured with those culverts are taken into consideration in arriving at the average, I cannot understand how the average can be correct.

Mr. A. E. Botts:—I misunderstood your interpretation. Of course, this report could not include any culverts that had passed out of existence at the time this inspection was made, and it is simply based on the ordinary inspection of what was found on the ground.

Mr. B. R. Leffler:—I will make a motion, to bring this thing to a head (as we have had quite some discussion), that the conclusions as given on page 125 on the service life of culverts be withdrawn as conclusions, and be referred back to the Committee.

Mr. Edwin F. Wendt:—I second the motion.

Chairman Geo. S. Fanning:—This Committee has investigated 10,663 culverts. That is the quantity Mr. Wendt wanted.

If you will refer to the table on page 126, you will find, under corrugated metal pipe, that 1,676 culverts have been inspected, of which 323 are 25 years old now, 46 are 30 years old, and 13 are 35 years old. The Canadian Pacific Railway in the West has, I understand, 16,000 metal culverts which are 25 years old or more. I am trying to be specific in answer to these statements that the life of corrugated metal is around 20 years.

Mr. Baldridge's criticism is well taken. This statement does not include culverts which have gone out of existence. That perhaps is more important with respect to these newer types of culverts, such as corrugated metal, than with respect to some of the older types, but it is an almost impossible thing to find and will not seriously change the result. It probably would slightly lower the life.

As I said before, I do not think that these life tables are absolute; they are relative. If we could get all of the masonry culverts that have gone out it would have the same effect. I think that the Engineer using these results has to read the report and find out how the materials differ and make allowances for that.

I would be very averse to having this sent back to the Committee. It is a second report, following last year's and adding more culverts, and it is very doubtful if we could get any further information that would change these conclusions radically. While they are headed "Conclusions," they are not offered for inclusion in the Manual. We are asked by the Board of Direction in each report to summarize the things that we think have been found and the results of the investigation. I would dislike to see this particular motion prevail.

Mr. Louis Yager (Northern Pacific):—I think there is a misunderstanding here as to just what is intended to be covered. Some of the speakers seem to think that this is in the nature of a research investigation to determine the relative life values of these different types of culverts. As I read the report, it does not purport to be that at all. It is merely a survey of the mortality statistics of the life of these culverts, and, as the Chairman has said, it did not take into consideration the quality of material which is a very important part, as we know, in the probable life of these various types of constructions.

These records are the weighted average results of the opinions of those men who inspected the existing culverts, and from that the Committee has projected the potential life of the culverts which are now in existence, and to that extent it can be said to be a relative relationship of the different types of construction. I think if that is kept in mind the report has value, but if it is to be construed to be a complete investigation of the different types of structures based upon their component materials, then I think it is beside the point.

The President:—I will ask the Chairman to state what the Committee desires to develop.

Mr. A. E. Botts:—Well, Mr. Yager's remarks were along the line of my statement, that we simply offer these conclusions as a guide. I said I thought they could be used for a future guide and we are simply offering it as information. I of course would like to see the report stand as written.

Mr. F. L. Nicholson (Norfolk Southern):—I think the difficulty that has arisen in connection with this report is largely due to the formula that has been adopted in arriving at these conclusions. Most of us who have had experience with corrugated metal pipe and vitrified clay pipe know very well that they have no such average service life as indicated. The whole report as based on this formula seems to indicate that the Committee has assumed that the deterioration in this pipe is uniform throughout its life period, when it is well-known that after the protecting coatings on corrugated pipe have become damaged and the protective coatings on vitrified pipe are damaged or removed the deterioration is not uniform but is progressively increasing as the years pass and the life is very much shorter. This formula based on uniform deterioration each year indicates a much larger service life than is actually obtained.

The President (interrupting):—There is a motion before the house with respect to the service life of culverts. For the reasons stated, it was moved by Mr. Leffler and seconded by Mr. Wendt that the matter be referred back to the Committee for further study. Are you ready for the question? All those in favor will so signify; contrary-minded, "no."

The Chair is in doubt. Will the "ayes" please stand? Now those opposed rise. The motion is lost, the Committee is sustained.

Mr. A. E. Botts:—The third subject assigned to this Committee is shown in Appendix F.

Chairman Geo. S. Fanning:—I think, before we refer to this subject, we had a motion before the house with respect to the deletion of the specifications on cast iron pipe, the recommendation at the top of page 128.

The President:—There is a motion before the Convention with respect to the Committee recommendations on specifications for cast iron pipe. Will Mr. Fanning restate his motion.

Chairman Geo. S. Fanning:—I move that the AREA specifications found in Bulletin 327, pages 6 and 7, for cast iron culvert pipe be withdrawn from the Manual. We recommend the use of ASTM Tentative Specification A 142–34T pending further consideration by the Committee.

Mr. A. E. Botts:—I second the motion.

The President:—It is moved and seconded that the present AREA specifications be withdrawn and the ASTM specifications substituted.

Mr. C. W. Baldridge:—I have no objection to withdrawing matter from the Manual but I want to call attention to the rules, Rule 4, of our Association regarding matter to be included in the Manual. I think I have it here. Rule 4 reads, "the Manual will only include conclusions relating to definite specifications and principles of practice as have been made the subject of special study by a standing or special committee and set up in a committee report, published not less than 30 days prior to the annual convention, and submitted by the committee to the annual convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction, should be reviewed by the American Railway Association, may be referred to that Association before publication in the Manual."

I have no criticism to offer to the ASTM specifications but they are not before us and they have not been before us, and under the rules we are barred from adopting ASTM specifications for inclusion in our Manual until they have been printed and presented to us.

Chairman Geo. S. Fanning:—We are not recommending the adoption of ASTM specifications at this time. We are asking that the AREA specifications be withdrawn from the Manual as being inferior to the ASTM specifications, and we recommend for your consideration the use of ASTM specifications until we have a chance to bring them in formally next year. The only action with respect to the Manual is the withdrawal of the present specifications.

Mr. C. W. Baldridge:—I do not see any particular need of withdrawing specifications from the Manual unless we have something to put in their place.

The President:—The question is now on the recommendation of the Committee, viz., will the AREA specifications in the Manual with respect to culverts be withdrawn or remain? All those in favor will signify by saying "aye"; contrary-minded, "no." The "ayes" have it and the recommendation of the Committee is approved.

Mr. A. E. Botts:—The third subject assigned this Sub-Committee is found in Appendix F, Specifications for Corrugated Metal Pipe.

Investigation last year indicated about 90 per cent of the railroads on a mileage basis were not using AREA specifications as now exist, and this Committee, upon this assignment, secured other specifications for corrugated metal pipe, made comparisons, and used AREA as well, and there were so many phases of the present specifications that would have been necessary to revise that we decided a redraft the most desirable thing to do.

The redraft is more in keeping with other specifications that now exist, such as AASHO and Federal QQ-C-806, and we feel is now in shape for general use by railroads.

We recommend its adoption for the Manual, replacing the present specification in supplemental Bulletin 327, pages 1 to 6 inclusive.

Mr. C. W. Baldridge:—The Committee that preceded this one on the platform, the Committee on Standardization, showed us that they have recommended for adoption by the American Standards Association, specifications for corrugated metal culvert pipe as given in Bulletin 327, page 3. That Bulletin is the supplement to the Manual of 1931, I believe. If we withdraw this matter from the Manual we are in the position of having recommended to the American Standards Association the adoption of something which we ourselves are now abandoning before they have time to act upon it. It appears to me that this matter should be referred back and have this Committee get in touch with or coordinate with our Standardization Committee.

The President:—In the light of Mr. Baldridge's remarks, I shall again put the question.

Chairman Geo. S. Fanning:—I do not understand that these specifications were ever referred to the American Standards Association.

Mr. C. W. Baldridge:—If you will refer to Bulletin 382, page 209, under "Roadway" and the list of matters referred to by the Standardization Committee, you will find this subject given as one of the subjects placed before the Association for standardization.

Chairman Geo. S. Fanning:—As I understand the recommendation of the Standardization Committee, it is a recommendation that certain specifications adopted by the AREA should be used generally by the railroads. It has nothing to do with the American Standards Association. Obviously, if the Association adopted a new specification it would take the place of the old one in this list. This list is simply for information. I do not think it has any particular bearing on the adoption or modification of specifications simply because they are included in this list.

The situation with respect to corrugated metal pipe is that we have a specification to which it cannot be manufactured, except in very small sizes and at a few plants and at abnormal cost. We are perhaps only a 10 per cent user of this material, and if Mr. Leffler and a few more of us had our way it would not be used at all. I am entirely in sympathy with that idea, but there is no use of having a specification in the Manual which is of no use to anybody. You cannot buy the material on that specification, so it seems to me we should make our specification the specification that is in universal use for the material you have to buy, and then buy it or not, as you want to. If you do not like to buy it under this specification, do not buy it. That is the way I am trying to look at it.

Mr. B. R. Leffler:—I am somewhat embarrassed. The Chairman of the Committee, after I was voted down, now agrees with me. I hardly know how to take it.

Chairman Geo. S. Fanning:—I should say I agree with Mr. Leffler that corrugated metal pipe is not a satisfactory material to use from the fact that its life is only one-half, for instance, that of concrete pipe. When we take into consideration the relative cost of the two we have found it to be absolutely not economical on that life. That is what I agree with him on.

The President:—Is there any further discussion?

Mr. E. M. Hastings (Richmond, Fredericksburg & Potomac):—In order not to have any misunderstanding whatever in the mind of anyone as to the items that were presented by the Committee on Standardization, they are not items that are put before the Association at this time as being recommended for standards to the American Standards Association. They are items which are now contained in our Manual or its supplements which the Committee on Standardization presents to you as worthy of your consideration for uniform practice. And this list which was presented this morning and is published here will be revised annually to conform with the action of the Association in its annual meetings. I just want to say that to have it fully understood and to emphasize that Mr. Fanning's understanding is correct. Anything that is withdrawn at this meeting naturally is withdrawn from this list.

The President:—With the explanations given, are you ready for the question?

Mr. J. E. Willoughby:—Table I does not seem to be very clear when it shows copper steel without indicating what percentage of carbon should be in it. We are not going to have steel until we put some carbon with the iron. Table I shows no percentage of carbon for iron when we know commercially pure iron has some carbon in it.

The President:—The question is on the approval of the Committee recommendation that this specification be accepted and printed in the Manual. Those in favor will so signify; contrary "no". The "ayes" have it and the report as presented by the Committee is accepted.

Chairman Geo. S. Fanning:—The fourth subject is "Formation of the Roadway." I will ask Mr. Paul Chipman, Chairman of this Sub-Committee, to offer that report.

Mr. Paul Chipman (Pere Marquette):—On page 133 of Bulletin 381, as Appendix G, are some remarks in regard to the revision of specifications. Changes now proposed are based, in large part, on a study of the specifications of a large number of roads, made by Mr. H. T. Livingston in 1934, as Chairman of the Sub-Committee which investigated the extent of adherence to the present specifications.

Following, on page 133, is a list of the principal changes which were made. The specifications themselves appear on pages 134 to 140 inclusive. On page 141 is a cross reference list by which the articles of the new specifications may be compared with those in the old ones.

This material is offered for inclusion in the Manual, replacing the present Grading Specifications.

The President:—It is moved and seconded that the information as presented be received for publication in the Manual.

(The motion was put to a vote and carried.)

Chairman Geo. S. Fanning:—Our fifth general subject is Roadway Drainage; on page 141 you will find a progress report.

Our sixth general subject is "Roadway Protection," and we simply report progress.

Our seventh subject is on "Tunnels." You will find the report on page 142, which I will ask Mr. F. W. Alexander, Chairman of the Sub-Committee, to present.

Mr. F. W. Alexander (Canadian Pacific):—The report of this Sub-Committee will be found in Bulletin 381, pages 142 to 155 inclusive. The first part of the report outlines collaboration with other committees and the cooperation that was rendered. Following this is a paragraph on Bibliography, with section headings as appear on pages 151 to 154 inclusive. For convenience this list has been subdivided under various headings.

Next in order is a short description of tunneling methods used on masonry tunnel construction on the North American continent during the last twenty years. The description of methods is illustrated by diagrams appearing on pages 147 to 150. It will be noted that modern railway tunnel construction does not follow the approved methods appearing on pages 42 to 44 of the Manual of 1929, and for this reason the recommendation will be brought in to withdraw the above from the Manual. This part of the report is given as information.

Next in order are "Recommended Revisions of Manual." In Bulletin 378, page 1, appears a paragraph on clearance reading as follows:

"The forms and dimensions of the clear space provided for single and double track tunnels should be such as to provide clearances established by the Special Committee on Clearances."

It is recommended that that be withdrawn, and it is proposed to substitute.

"The interior dimensions of clear space provided for single and double track tunnels shall not at any point be less than tunnel clearance approved by the AREA."

The next, coming down the line is the "Note:—Due to the outline of tunnel sections it may not be desirable to follow the form of clearance diagram, so word 'form' should be deleted and 'not less than' put in to cover." I so move.

The President:—It is moved by the Committee that the changes recommended be received for publication in the Manual.

(The question was put to a vote and carried.)

Mr. F. W. Alexander:—For reasons already given, pages 42, 43 and 44, Tunnel Construction, Manual of 1929, should be withdrawn. I move the adoption of this recommendation.

The President:—It is moved and seconded that the material on the pages recited, now in the Manual, be withdrawn.

(The question was put to a vote and carried.)

Chairman Geo. S. Fanning:—Our eighth subject is "Fences," on which progress is reported. Our ninth is on "Signs," on which you will find a report on page 155. Arising from the fact that all of the material now in our Manual is obsolete and is not used to any extent on any railroad, it is the recommendation of this Committee that all of the material on "Signs" be withdrawn from the Manual.

(The motion was regularly seconded, put to a vote and carried.)

That completes the report of the Committee.

The President:—Mr. Fanning, I desire to thank you for the excellent and worthwhile report of your Committee. In connection with its work, I desire at this time to announce the approval by the Board of Direction of the appointment of Mr. H. W. Legro from this Committee to represent the Association at the Conferences on Physical Properties of Soil at Harvard University on June 22–26.

The Committee is now excused with the thanks of the convention (Applause.)

DISCUSSION ON STRESSES IN RAILROAD TRACK

(For Report, see pp. 101–102)

Dr. A. N. Talbot (University of Illinois):—The report of the Committee is found on page 101 of Bulletin 381. That report concerns the general work of the year.

Instead of reading it I wish to present a report of observations and tests made on the stretches of welded rail in the track of the Delaware and Hudson Railroad at Albany and Schenectady, the last of the measurements and observations having been made in colder weather in January.

Tests on Delaware and Hudson Track made with Welded Rail: Tests and observations of the welded rail were made on one stretch at Albany and two stretches at Schenectady. The length of the welded stretch tested at Albany was 2660 ft. (0.5 mile) and at Schenectady 4460 ft. (0.85 mile) and 6980 ft. (1.32 miles).

It should be stated that all this track was high grade, well built and substantial, with 130- and 131-lb. rail fastened to the tie-plate by clips and the tie-plate screw-spiked to the tie and with the best of ballast and shoulders.

To begin with, something should be said as to the purpose and methods of the tests. Perhaps the word observations may better indicate the nature of the work.

The purpose of the tests: To learn the amount and distribution of changes in length in the rail itself all along a stretch of welded rail and particularly at places near the two ends of the stretch, and thus to find something of the magnitude of the anchorage forces (or restraining forces) provided by the track structure at and near the ends and possibly at various points along the stretch, and likewise to learn something of the values of the temperature stresses set up in the rail—all due to the effect of changes in temperature such as occurs from morning to afternoon or from summer to winter. In other words, to find (1) changes in length in the rail at any place along the stretch, (2) anchorage or restraint at any place along the length, (3) temperature stresses set up in the rail at any place.

The method: Gage lines on the web of rail (gage length of 8 in.) at various places along the stretch—relatively close together at the end portions of the stretch over a distance of five rail lengths; farther apart through the intermediate portion—every 4 or 5 rail lengths. Readings with a strain gage taken continuously over the stretch as expeditiously as possible and repeated at different times. Coincidentally with taking the strain gage measurements, the temperature of the rail was taken by two men by means of an open-ended thermocouple and portable potentiometer, which quickly gave the rail temperature at the points along the rail. Strain gage readings and temperature readings were also taken on a standard bar or comparator, and likewise on short pieces of rail. In the tests in summer weather, readings were taken on a cool cloudy day (rail temperature say 58 deg.) and in the hotter part of a day (rail temperature say 90 deg. to 105 deg.). In the test in winter weather, readings were taken at a rail temperature of about 16 deg., with air temperature as much as 13 deg. colder.

It should be said that this test work was attended with many difficulties, caused by cold, snow, wind, etc., and that many precautions were taken in regard to gage holes, instrumental manipulation, temperature calibrations and corrections, and checks in the work. Likewise the reduction of data and comparison of results involved careful study and consideration. It is believed that the results obtained are trustworthy and definite in telling a story of the change in length of the rail and of the temperature stresses set up.

Tests and observations were made on one stretch of track at Albany (a half-mile in length) and two stretches at Schenectady (one 0.85 mile and one 1.32 mile). The data of the tests on the 0.85 mile stretch at Schenectady have been chosen for presentation this morning. The tests of this stretch of track have less variable conditions of temperature and support than were found on the other stretches of track.

It should be said that on this stretch of welded rail there is a long 4 deg. curve at the north end, a 4 deg. curve north of the central portion, a 2 deg. curve at the central portion and a long 30 ft. curve towards the south end of the stretch. The grade was 0.75 per cent up-grade southward and in the direction of traffic.

The discussion will take up (a) Changes in length in the rail at the various points along the track, (b) Temperature stresses in rail, and (c) Various results and observations found by the tests.

In the view in Fig. 1, one man (the recorder) is holding the ends of the wires of the thermocouple to touch the head of the rail (or it may be another part of its surface) and the other is reading the potentiometer. Only a brief time is required to get the temperature of the rail. The fastening of the rail to the tie-plate is also shown in this view.

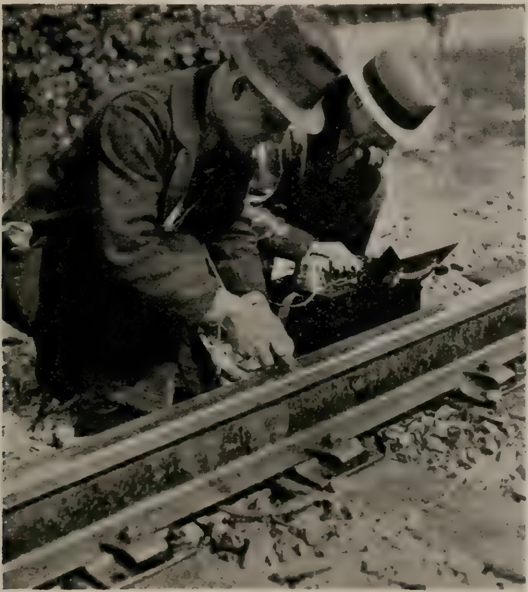

Fig. 1.—Measurement of Rail Temperature on D. & H. Welded Track.

Fig. 2 represents changes in length in the rail along this 0.85 mile stretch of welded rail for changes in rail temperature from a base temperature of 58 deg., which was the rail temperature on a cool, cloudy day in the summer test. Distances from the north end are given in rail lengths at the top of the diagram, 120 in all. Alinement is also indicated at the top of the figure. The change in length (increase or decrease) of course was found from the difference in strain gage readings at the different times and was converted into unit strains (inches per inch). However, as an aid to simplicity of comprehension, these unit strains have been expressed as equivalent stress, pounds per square inch, such as would occur under the application of tension or compression without change in temperature. Please remember, however, that on this slide pounds per square inch refers to the equivalent change in length; it does not give the stress put into the rail by the temperature change—that will be shown on another slide.

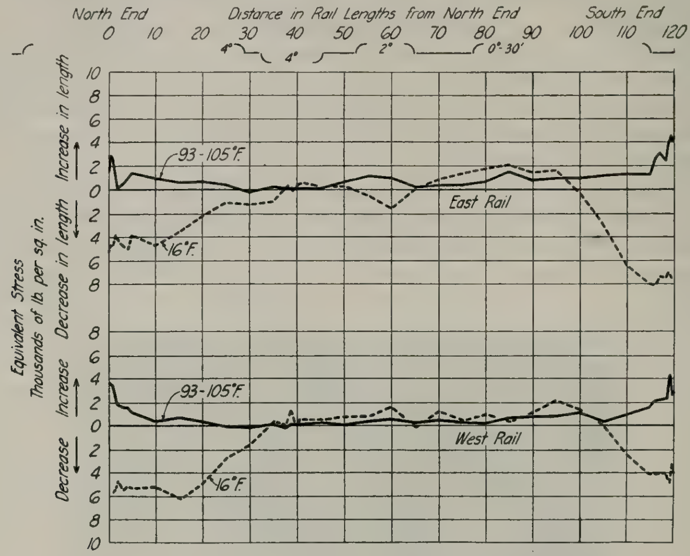

Fig. 2 Change in Length in Terms of Stress Base 58°

In this slide, then, the ordinates (vertical distances) represent the change in length in the rail expressed as equivalent stress in thousands of pounds per square inch. If there is little or no change in length, regardless of the change in temperature, the rail has been held rigidly to prevent the natural expansion or contraction, as occurs throughout the larger part of the length. If at a given point there is some change in length though not as great as that due to the given change in temperature, as occurs in the end portions, there must exist a corresponding suitable holding or restraint.

The plotted lines in the upper part of the slide are for the east rail, those in the lower part for the west rail. The rail temperatures for the full line curves (late summer tests) varied along the track from 93 deg. to 105 deg., but were fairly uniform at about 100 deg. over all the track except for 10 rail lengths at the left portion where there was shade. The broken lines (winter tests) are for a rail temperature of 16 deg., which was very uniform over the whole stretch. Let me repeat that both summer and winter values are related to the cloudy day temperature of 58 deg. in the summer tests as a base value. Upward values represent increases in length and downward values decreases.

It is at once apparent from the slide that a characteristic of this track is that throughout all the intermediate portion of this 0.85 mile stretch the rail is held with sufficient restraint such that practically all change of length is eliminated for the entire range of temperature of the summer and winter tests, except for minor changes at different local points. The change of length in the rail in the high temperature run with respect to the 58 deg. run was a slight increase equivalent generally to less than 1000 lb. per sq. in. over most of the length, as shown by the full line curve. The low temperature run shows the same characteristics for a temperature change from 58 deg. to 16 deg. over almost as long a distance.

The principal changes in length of rail were observed at the end portions of the stretch as shown at the left and right portions of the diagram. The results for the high temperature run are complicated at the left end by a markedly lower temperature due to shade from a high bank and trees, so the right end portion is probably a more representative condition, or at least a better illustration of the action of the track under uniform conditions. Here at the right end the rail under the high temperature as compared with the measurements at 58 deg. increases in length over a distance of about 5 and 15 rail lengths on the two rails. Before the time of the winter observation a repair and readjustment of the track at the right end of the stretch had changed the end conditions, and under the low temperature the decrease in length extended over about 15 and 20 rail lengths as compared with the 58 deg. run taken in the previous summer. In the summer tests, the rate of change of length increased considerably over the end rail lengths for this and other stretches tested, the greater part of the change occurring in as little as 5 rail lengths. It should be borne in mind (to repeat again) that these values are unit changes in length determined directly from strain gage readings and for convenience expressed in terms of stress, but they are not the temperature stresses.

It will be well before going on to the next slide to state the significance of these changes in length with respect to their effect on the actual temperature stress in the rail. Wherever we observe a change of length in the same direction as the change that would be due to the change of temperature without restraining action, there is present also a lessening of the temperature stress in the rail. Thus, for example, in the end portions of a stretch where there is only partial restraint a temperature increase lengthens the rail as shown in Fig. 2 and results in a decrease from the full temperature stress present elsewhere in the rail. A decrease in length that accompanies a decrease in temperature also decreases the stress from that which would be present under conditions of full restraint; the actual stress in this case is of opposite nature. At the middle portion where little or no change in length is observed, approximately the full temperature stress is present that corresponds to the temperature range.

From the values of the changes in length given in Fig. 2 and the rail temperature measured at a particular point, the stress in the rail due to the change in temperature from 58 deg. was calculated. Fig. 3 shows these temperature stresses for the summer test at 93 deg. to 105 deg. and the winter test at 16 deg.

It will be seen from the slide (Fig. 3) that throughout all the intermediate portions of the stretch the compression in the rail for the summer test ranged from say

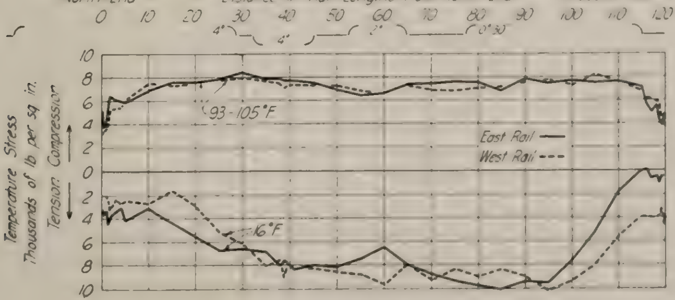

Fig 3 Temperature Stresses in Rail. Base 58°

7,000 to 8,000 lb. per sq. in., and for the winter test the tension ranged from 8,000 to 10,000 lb. per sq. in., if taken on the basis of a temperature of 58 deg. The total range in temperature thus was nearly 90 deg. and the total change in temperature stress from compression to tension was say 17,000 lb. per sq. in. This stress corresponds approximately to the stress equivalent calculated from the range in temperature, which indicates that, except for local conditions along the length, the rail over the main portion of the stretch on the average is held rigidly from changes in length through all this range of temperature.

It has been noted that the stresses given for both the summer and the winter tests have been based upon the readings taken at 58 deg. rail temperature. Having this set of readings an opportunity is given to learn the general uniformity and variations of both the summer and the winter tests. It is evident that the use of this medium temperature as a base is equivalent to assuming that the temperature stress is zero at 58 deg. This assumption will not affect the relative position of the upper curves and the lower curves with respect to each other. For any other base temperature than 58 deg., the corresponding values of the temperature stresses may be seen by raising or lowering the zero axis by a stress equivalent to the change in reference temperature desired, if the rail is assumed to return to its earlier position at a given temperature. Thus, if the temperature when the rail was free from temperature stress was 25 deg. higher than 58 deg., the axis would be raised 5,000 lb. per sq. in. and a compression value of 8,000 lb. per sq. in. would become 3,000 lb. per sq. in., while a tension value of 10,000 lb. per sq. in. would become 15,000 lb. per sq. in. As the rail was laid at a fairly high temperature it may be expected that a change of axis such as 5,000 lb. per sq. in. more nearly represents the actual temperature stresses developed in the rail at the time of the two tests.

A word as to the anchorage of the end portion of a stretch of welded rail to give fixity to the intermediate portion: Considering a range of stress of 90 deg. and a change in temperature stress of 17,000 lb. per sq. in., the total anchorage force required at the end portion of 131-lb. rail for this change in temperature would be about 220,000 lb. for each rail. This force is required at each end of the fixed portion comprising the main middle part of the welded stretch. It is apparent that except for some possible fixity at the extreme end this anchorage is gained in the length of track that shows increasing temperature stresses toward the fixed portion, giving a sloping line in the diagrams. If the rate of increase along this length is uniform (a straight line in the diagram, the anchorage force given by the ties may be considered to be applied to the rail rather uniformly from tie to tie. At various places along the anchoring portion, the rate of application of the anchorage force may be considerably greater or less than the average. It is perhaps true that the individual tie anchorage force may vary in amount in some way from the beginning of the anchorage to the intermediate portion. It should be said also that it has not been fully established whether a large range of temperature involves a longer length of anchorage than a smaller range, and if so how this length varies.

The end portions of the stretch have different conditions from the intermediate portion and require further discussion. As is to be expected, some distance along the end portions of the welded stretch is needed to acquire the anchorage and to give fixity for developing the greater compressive or tensile stresses found in the intermediate portion of the stretch. For the summer test (cool and cloudy day and bright and warm day) nearly the full temperature stress was acquired in 5 rail lengths from the ends of the stretch. The apparent compressive stress shown at and near the ends of the stretch is due partly to taking 58 deg. as the base, and the higher temperature existing at laying time would probably reduce the actual value of this compressive stress at 105 deg., by say, 4,000 or 5,000 lb. per sq. in. Besides, the joint bars at the ends of the stretch perhaps carried stress to the next stretch of rail and, too, the ends moved ¼ in. or so in the change of temperature from 58 deg. to 105 deg.

In the winter tests, the greater part of the tension found in the intermediate portion is acquired between a point a few rail lengths away from the end and another point 15 or 20 rail lengths farther on. Through the first 10 or 15 lengths of the north portion and the first 5 lengths of the south portion the tensile stress is fairly uniform, amounting to 3000 or 4000 lb. per sq. in. if counted from the 58 deg. temperature, and to about 8000 lb. per sq. in. if counted from a probable laying temperature, though the actual stress at the ends is not known because of changes made in track in November, as referred to in the following paragraph. Most of this stress is doubtless applied at the ends of the stretch from the rails beyond through the joint bars there.

As to this uniformity of stress over the 5 and 15 rail lengths of the two end portions: At the north end the data and the condition of the track gave evidence that final work on this portion of the track had been made after the date of the summer test (including the insertion of a second rail joint and a short piece of rail), which resulted in readjustments affecting the relations of the basic measurements from other causes than temperature. The measurements indicate a longitudinal rail movement here of an inch or more during this final work. At the south end, the east rail at the insulated joint, connected to the adjoining welded stretch of rail by joint bars, broke through the bolt holes with a temperature drop in November. The insertion of a new piece of rail next to the insulated joint and also of a second rail-joint changed the amount and distribution of stress over some unknown distance. In the adjustment of this part of the track the conditions of stress in the west rail were also changed. It may be said then that the presence of uniform stress through this distance

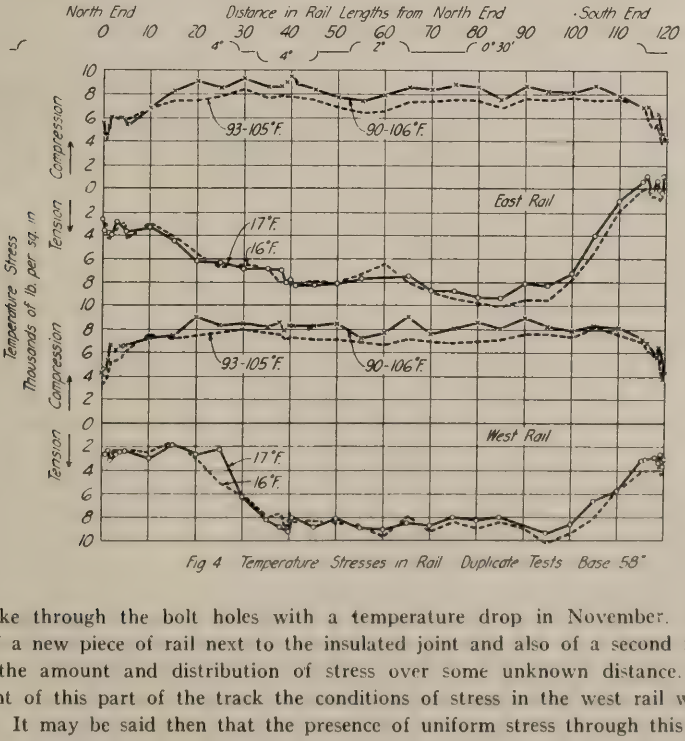

Fig 4 Temperature Stresses in Rail Duplicate Tests Base 58°

of 10 and 5 rail lengths at the two ends of the stretch is probably largely due to changes made in the track after the summer test was completed.

In Fig. 4, the temperature stresses found in a duplicate test are shown by the full lines, while the dotted lines give the results of the test already shown in Fig. 3. The slide indicates that the two sets of tests give results quite consistent with each other.

It may be of interest to see what forces this tie anchorage involves. An examination of the sloping parts of the diagram to learn the rate of change of stress in the rail seems a promising way of getting at the anchorage developed at the tie. See the sloping portions in Fig. 3 and 4. An examination shows considerable variation in the tie anchorage. Computing average anchorage per tie over different lengths (taken from the increases in stress in rail from point to point), it is found that sometimes the greater part of the anchorage is attained in 15 or 20 rail lengths and sometimes a considerable amount in 2 and 4 rail lengths. A study of all the eight series of the summer and winter tests on the 0.85 mile stretch at Schenectady and the eight series of tests on the one-half mile stretch of the northbound track at Albany, using an assumed laying temperature and assuming that changes in length are proportional to changes in temperature, gave values of average tie anchorage developed at certain places of varying lengths ranging from 100 lb. to 270 lb. per tie per rail for the summer tests (calculated between an assumed laying temperature and a cloudy day temperature), and from 165 lb. to 470 lb. for the winter tests when compared with the cloudy day observations of the summer test (58 deg.). A combination of high and low temperature tests gave values ranging from 270 lb. to 740 lb. per tie per rail. It is apparent that the values of the anchorage vary considerably at different places and that the distribution of the anchorage varies from place to place and from time to time. Besides, little is known of the relation of the tie resistance to the "give" of the tie longitudinally of the track.

From the strain data at and near the end of the stretches, it is thought that the rail-joints of three of the ends of the welded stretches at Schenectady transmitted as much as 6,000 lb. per sq. in. of rail section to the adjoining rails.

In closing, a few general observations on various aspects and actions of the stretches of welded track may be made:

All the welded stretches tested had kept their alinement well even on the curves including the 7° 30′ curve at Albany, so far as could be seen from the test and the general inspection and from the lateral measurements made by the Engineers of the Delaware and Hudson Company.

The longitudinal movement at the ends of the welded stretches and at points along the length, due to temperature changes, was small, say from 0 to ½ in. or a little more, and little if any greater than is often found in ordinary track.

No noticeable movement of the ties in a direction longitudinal of the track was seen.

It is apparent that at the end of a welded stretch of rail, a tensile or compressive force of considerable magnitude may be transmitted to the adjoining rail (whether welded or not)—a condition that warrants consideration and which may be beneficial or otherwise according to circumstances.

It may be remarked here that observations at various times and places on ordinary track with tight well-fitting joints have shown small movements at joints over a wide temperature range, indicating that large temperature stresses may be present in ordinary track.

The deep snow at the time of the winter tests, coming up on the head of the rail, kept the rail temperature quite above that of the air temperature in the cold weather.

On a bright, clear day in summer (not a hot day), the rail temperature was found to be 38 deg. higher than the air temperature of 68 deg. In another observation the rail temperature was 35 deg. higher than an air temperature of 90 deg.

The few breaks in rail on the welded stretches have left only small gaps, so that they were not troublesome and replacements were easily made.

In the welded stretch tested at Albany the anchorage at the end portions was of a character similar to that found at Schenectady and was acquired in from 5 to 10 rail lengths. Due to the presence of under-crossings and viaducts and other variable conditions, the summer rail temperatures and temperature changes were quite variable along the stretch, resulting in the development of variable anchorage forces at points along the length, as is to be expected.

It is recognized of course that the flexural stresses developed in the rail by the loads of traffic will be superimposed on the temperature stresses and the two sets of stresses at any point in the height of the rail must be added or subtracted according to their nature. To what extent the presence of high tension temperature stress will affect the growth of transverse fissures may be an interesting question.

It is planned to continue tests on this track and on other welded track. In such a departure from usual practice, a year or two of time may bring out all the characteristics of the action of such track (Applause).

The President:—Professor Talbot, I wish to thank you in the name of the Association for your splendid report, which well merits careful study by every Engineer interested in the advances in track construction and maintenance which must ultimately result from the explorations of your Committee. May I again assure you and the Committee that the Board of Direction is mindful of the increasing interest of this Association in the value of the work which has been so well pioneered by the Committee under your leadership. I am hopeful that added facilities and funds may soon be made available for a more extensive experimentation and research studies along the lines which are being developed. The Committee is now dismissed with the thanks of the convention (Applause).

DISCUSSION ON YARDS AND TERMINALS

(For Report, see pp. 307–382)

Mr. M. J. J. Harrison (Pennsylvania):—The report of the Committee on Yards and Terminals appears as the first report in Bulletin 383. The Committee offers a report at this time on Revision of the Manual, a report as information on Coal Transfer Terminals, a recommendation as to Manual material on Scales Used in Railway Service, and a report, submitted as information, in the form of a Bibliography on Subjects pertaining to Yards and Terminals.

Progress is reported on the two other assignments—Hump Yards and Expediting of Freight Car Movements Through Yards, collaborating with Committee XXI.

Under the heading, "Revision of Manual," your Committee submits material found on pages 308 to 333 inclusive of the Bulletin. This is submitted as a substitute for the present Manual material. It is based on the material now appearing in the 1929 Manual and supplements, but has been completely rearranged and rewritten.

I should like to have your instruction as to how you desire to consider this. I would say, for your information, that there is much of this that is rewritten from the purely editorial standpoint. There is some new material in here, and on page 333 is listed the items and sections of the 1929 Manual and Supplements which the Committee recommends be deleted.

The President:—Let the Committee proceed in the customary manner, with reports from its Sub-Committees, if there are recommendations requiring action by the convention, please make them.

Chairman M. J. J. Harrison:—The material starting on page 308 under the general designation of "Terminals," is essentially new material, designed as an introduction to the entire chapter. The idea of the Committee in preparing this material which is now before you was to set it up in an orderly manner, starting with the general designation of "Terminals," and proceeding from that through "Passenger Terminals," "Freight Terminals," "Locomotive Terminals" and "Scales", the general subjects which were assigned to the Committee.

Much of the material presented under the general heading of "Terminals" is new material. Much of the material presented under the other headings is rewritten material from the 1929 Manual and Supplements.

I should like to bring this before the convention by offering a motion at this time that this material as here presented be accepted by the Association as a substitute for corresponding and similar material now in the Manual.

The President:—It is moved and seconded that the material presented by the Committee be accepted and substituted for that now appearing in the Manual.

(The question was put to a vote and carried.)

Chairman M. J. J. Harrison:—Starting on page 333 and continuing to page 343 inclusive, there will be found a report, submitted as information, on Coal Transfer Terminals. This is developed as a result of questionnaires, specific rather than general, and knowledge of various members of the Committee, and sets forth, with the help of certain plans of some six coal transfer terminals, material which, in the judgment of the Committee, is of value to the Association for reference but hardly justifies its adoption as Manual material.

In the name of the Committee I would ask that Appendix B, covering Coal Transfer Terminals, be accepted as information.

The President:—It will be so received.

Chairman M. J. J. Harrison:—Beginning on page 344 of the Bulletin and going through to page 357 inclusive, your Committee offers at this time a revision of "Specifications for the Manufacture and Installation of Four-Section, Knife-Edge Railway Track Scales."

This revision was brought about from several different causes, chief among which can be mentioned the desire of this Association, through its Standardization Committee, to advance to the status of National Standards such of its specifications as are adaptable to such advancement. It is also to be noted that the old specifications which were originally adopted in 1920, now in the Manual, were inconsistent in certain respects. This material, beginning on page 344, has been developed as a substitute for that and also for certain other documents which are now in existence, not AREA Manual material.

I should like to say that in developing this material the active collaboration of the National Bureau of Standards has been obtained and that that Bureau has tentatively indicated that it would concur in these specifications if adopted by the AREA. It also carries with it, I am glad to say, the endorsement of the National Scale Men's Association.

I should like to move the acceptance of the material starting on page 344, under the heading, "Specifications for the Manufacture and Installation of Four-Section, Knife-Edge Railway Track Scales," as a substitute for the present Manual material, and the adoption of this material for the Manual of the Association.

(The motion was put to a vote and carried.)

Chairman M. J. J. Harrison:—In order to be consistent, I will now move the deletion from the Manual of the endorsement appearing on page 66 of Bulletin 327, July, 1930, of "Specifications for the Manufacture and Installation of Light Industrial Service Railway Track Scales."

The reason for moving that that endorsement be deleted is that the action just taken makes it unnecessary further to carry that endorsement in the records of the Association.

The President:—If there is no objection we will consider it adopted.

Chairman M. J. J. Harrison:—Beginning on page 358 and continuing through to page 375 inclusive, your Committee offers for consideration a code of "Specifications for the Manufacture and Installation of Motor Truck, Built-In, Self-Contained and Portable Scales for Railway Service."

Last year the Committee offered and the Association accepted similar specifications. Since that time the situation has changed a little bit, and it has become obvious to the Committee that the original specifications could be considerably improved particularly since, by making certain changes, much better cooperation could be obtained from the other parties at interest in this particular matter.

Your Committee's conception of its responsibility is that it should take a course which is susceptible of a maximum collaboration from other parties at interest. This material beginning on page 358 is therefore offered as a substitute for similar material adopted one year ago, and I move that it be so accepted and adopted.

(The motion was regularly seconded, put to a vote and carried.)

Chairman M. J. J. Harrison:—Beginning on page 375, under the heading of Appendix D, "Bibliography on Subjects Pertaining to Yards and Terminals Appearing in Current Periodicals," the Committee takes a great deal of pleasure in submitting a bibliography compiled by Mr. E.E.R. Tratman, which the Committee feels will be of considerable value. We ask that this be accepted as information.

The President:—It will be so accepted.

Chairman M. J. J. Harrison:—That concludes the report of the Committee on Yards and Terminals.

The President:—Mr. Harrison, I thank you for your report. The Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON WATER SERVICE, FIRE PROTECTION AND SANITATION

(For Report, see pp. 383–415)

Mr. R. C. Bardwell (Chesapeake & Ohio):—The report of Committee XIII—Water Service, Fire Protection and Sanitation, is presented in Bulletin 383, pages 383 to 415 inclusive.

The report on the first assigned subject, Revision of Manual, is covered very fully. The Water Service section of the Manual has been rewritten in order that it would be in the best shape for publication in the new Manual.

The report of this Sub-Committee will be presented by its Chairman, Mr. E. M. Grime.

Mr. E. M. Grime (Northern Pacific):—In making a critical study of the Water Service section of the Manual, the Committee first finds that it is desirable to make an entirely new arrangement of material. This has been done according to a sequence, the first section of which includes, in order, definitions, general principles of water supply, including means of procuring water, methods of pumping water, special devices used, and specifications for important details peculiar to water supply. The second section includes various details pertaining to the art of water softening developed during the past thirty years. This is followed by specifications for chemicals used, the special methods of locomotive operation which are desirable for securing the best results from softened water, requirements for water used for drinking purposes, records for accounting purposes, and water service organization.

In the next case the Committee finds that much material in the Manual is no longer receiving consideration and therefore should be deleted in an effort to produce a section of brief but essentially live topics of practical value to the busy Engineer as well as the Executive. Also, some material now in the Manual, valuable for reference but yet seldom used, has been deleted and reference made to the location by page and volume where same may be found in the Manual or the Proceedings.

In conformity with the foregoing, your Committee finds as follows: Eighty-two definitions now in the Manual cover terms which have come into such common usage that it seems unnecessary to continue to publish them in the Manual.

These are shown on page 384, and as they are before you it seems unnecessary to read the various definitions.

I move that these be deleted.

The President:—It is moved and seconded that the definitions be deleted as recommended by the Committee.

(The question was put to vote and carried.)

Mr. E. M. Grime:—The Committee desires at this time to add nine definitions which are technical in their nature and, with the exception of the first, pertain to the subject of Sanitation, which is now a part of the Committee's assignments.

These definitions are as follows: "Blowdown, deodorant, disinfectants, fumigant, formalin, germicide, insecticide, liquor cresolis, phenol coefficient."

The Committee moves that these definitions be included in the Manual.

(The motion was put to vote and carried.)

Mr. E. M. Grime:—On pages 385, 386, 387, 388 and 389 of the Bulletin are shown various subheads as now appearing in the Manual. In these we desire to make either a deletion, a rearrangement of material, or add some new material. I will read each heading, briefly indicating what the Committee recommends, and if there is no objection, pass to the next heading, and finally make a motion for your approval for the entire list. Each of these subjects has been given careful attention and study by a large majority of this Committee, and to conserve time it seems unnecessary to read all of the printed substance appearing on these pages.

"General Principles of Water Service." The material under the heads of "Quantity" and "Quality" has been revised, as appears on page 385.

"Supply—Source." The last part of the fourth paragraph under this heading in the Manual has been deleted and a substitution is made as shown. In connection with this, the discussion on Impounding Reservoirs, pages 915 to 919 in the Manual, is deleted, but reference is shown to where this material may be found. This subject of Impounding Reservoirs, while valuable, is used infrequently.

On the subject, "Quality of Water—Method of Treatment," it is desirable to add here the following chemicals which are now necessary under modern water treating conditions: "Barium compounds, caustic soda, ferrous sulphate, ferric salts, sodium phosphate salts, sodium aluminate, sulphate of alumina, tannins, and proprietary boiler compounds."

Under the heading of "Storage," which is found on page 65 of Bulletin 327, we desire to eliminate the fourth paragraph covering the subject of Impounding Reservoirs.

Under the heading of "Pumping Plants—Buildings" there is an article on Pump Houses, on page 915 in the Manual, and an article on Heating Water Station Buildings on page 951. These two are combined in one article, as shown at the bottom of page 385 and the top of page 386. No material has been added but what is there has been rearranged and condensed.

'Steam Equipment." This material is all deleted except the formula indicating the method of arriving at horsepower required for pumping water. Under modern conditions, the use of steam for operation has been almost completely superseded by either fuel oil engine or electric drive.

"Deep Well Pumping Equipment." This material has been rearranged and revised to be in accordance with the most recent designs in pumping machinery.

"Centrifugal Pumps." The material as appearing in the Manual on pages 893, 894, 895 and 896 has been condensed and revised to conform to the extensive development which has taken place in the design of centrifugal pumps during the past few years, and this new material is recommended for that now in the Manual.

"Hydraulic Rams." The hydraulic ram is so seldom used in railway service that to conserve space it was deemed advisable to delete the technical part of the discussion appearing on pages 896, 897, 898 and 899 of the Manual, leaving simply a reference to where this material may be found.

"Relative Economy of Different Types of Plants," Manual page 898. The first two paragraphs and the first line of the third paragraph under this heading in the Manual are deleted, as they cover only the special case of fuel oil engine which is considered elsewhere in the Manual.

"Water Meters for Use in Railway Service—Methods of Testing, Reading and Checking Consumption." Under this heading the Manual contains a paragraph on "Accuracy of Meters," and a paragraph on "Maintenance." The data on Accuracy is deleted because it is found in most meter catalogs, and the paragraph on Maintenance is deleted as covering details which are self-evident.

"Pipe for Service Lines, Three Inches and Under in Size." Under the head of "precaulked pipe" in the Manual we desire to add the size one and one-half inch, and we delete the second and third sentences of paragraph 6 as being superfluous since this type of pipe has come into common usage.

"Standardizing Valves and Packing." For the sake of brevity this matter has been consolidated and rewritten as appearing in the center of page 389.

I move the adoption of all the changes as per the headings previously read.

The President:—It is moved and seconded that the changes recommended by the Committee be adopted.

(The question was put to vote and carried.)

Mr. E. M. Grime:—"Specifications for Cast Iron Pipe and Special Castings," appearing on pages 902 to 907, and also "Specifications for Hydrants and Valves," pages 907 to 913. These specifications were reprinted by permission from the American Water Works Association and by direction of the Board Manual Committee they are deleted and a footnote reference made to show where the material may be found.

"Specifications for Steel Water and Oil Tanks." We desire to make one change in this specification and that is to add an item of thickness for the roof plates, making same 3/16 inch.

I move adoption of this change in the specification.

(The motion was put to vote and carried.)

Mr. E. M. Grime:—"Steel Substructures for Water Tank." This appears on page 941 of the Manual and under the heading of "Workmanship" we desire to add: "All connections for steel substructures shall be bolted and the bolts shall be furnished as a part of the steel."

I move adoption of this addition.

(The motion was put to vote and carried.)

Mr. E. M. Grime:—The Specifications for Soda Ash appear on page 390 of Bulletin 383. The only change desired in these specifications is under the head of "Chemical Properties." Change "Normal Sodium Carbonate 95.0 per cent," as now reading, to "Normal Anhydrous Sodium Carbonate 98.0 per cent."

Under the heading of "Packing," eliminate the kind of material for bags, and that they shall weigh not more than 50 pounds, making this specification read:

"Soda ash shall be packed in suitable bags of not more than 100-lb. net weight."

I move approval of this change in the specifications for soda ash.

(The motion was put to a vote and carried.)

Mr. E. M. Grime:—"Specifications for Hydrated Lime," page 391 of the Bulletin.

The only change it is desired to make in this specification is the substitution of a one-pound sample for the two-pounds sample now required.

I move adoption of this change.

(The motion was put to vote and carried.)

The President:—Let me suggest you proceed with your report unless or until there is a question or an objection from the floor. A motion will then be in order for some action on the report of the Committee as a whole.

Mr. E. M. Grime:—"Specifications for Quicklime." This specification has been largely rewritten but appears in complete form on pages 392 and 393. There are very few changes of any consequence in that specification.

"Specifications for Sulphate of Alumina," appearing at the bottom of pages 933, 934 and 935 of the Manual. The only changes in this specification are under the head of "Sampling," where a one-pound sample will be required instead of five pounds in the old specification; under the head of "Packing," the words "suitable bags" replace "cloth or duck bags," and the minimum net weight is changed from 50 to 100 pounds.

"Specification for Sulphate of Iron." This has been largely rewritten but with very slight changes.

I move the adoption of these changes in the specifications as mentioned.

The President:—It is moved and seconded that the changes recommended by the Committee be adopted.

(The question was put to vote and carried.)

Mr. E. M. Grime:—On page 395 occurs the heading, "Minimum Quantity of Scaling and Corrosive Matter Which Will Justify Treatment."

It is desired to change this heading, making it read: "Minimum Quantity of Scaling and Corrosive Matter Which Will Justify Complete External Treatment."

This article has been amplified in minor particulars to conform with the refinements now prevalent in water treating matters, and an explanation is added concerning the value of 13 cents per pound for solids removed.

I move adoption of the revised article as printed on pages 395 and 396.

(The motion was put to vote and carried.)

On page 396 is an item on "Foaming and Priming." The original article appearing on pages 919 and 920 of the Manual does not conform closely to present practice, and it is desired to delete the material now in the Manual and substitute the item as appearing at the bottom of page 396. In this connection, let me call your attention to a typographical error in the bottom line where the words "conclusive of" appear. This should be "conducive to," making that sentence read: "(Carrying water unnecessarily high in the boiler is conducive to both foaming and priming.)"

I move adoption of the revised paragraph.

(The motion was put to vote and carried.)

This Committee accepts forms adopted by the Committee on Records and Accounts, covering water service records and substitutes the following for forms now appearing in the Manual:

Form 1330—Cost of Water Production.
Form 1331—Monthly Report of Water Station Operation.
Form 1332—Quarter-Monthly Report of Water Treating Plant Operation.
Form 1333—Record of Water Station Facilities.
Form 1334—Record of Deep Wells.

I move approval of these forms for the Water Service section.

The President:—It is moved and seconded that the forms as altered in the manner recommended by the Committee be approved.

(The question was put to vote and carried.)

Mr. E. M. Grime:—"Sewage Disposal Where Sanitary Facilities Are Not Available." on page 397, and also the article on pages 398 and 399 on "Disinfectants, Deodorants, Fumigants and Cleaning Materials."

Since this Committee has been assigned the subject of Sanitation, we feel that these two articles, covering some of the essential features of this class of work, should be included in the new Manual for ready reference, and I therefore move adoption of these two paragraphs for inclusion in the Manual.

The President:—It is moved and seconded that the two subjects as reported by the Committee be adopted for printing in the Manual.

(The question was put to vote and carried.)

Mr. E. M. Grime:—This completes the work of revision of the Manual.

Chairman R. C. Bardwell:—Your Committee desires to report progress on Subject 2, "Relation of railway fire protection equipment to municipal and privately owned waterworks," and 3, "Use of phosphates in water treatment." It is hoped that we will be able to present reports on these subjects during the coming year.

The report on Subject 4, on "Pitting and Corrosion of Locomotive Boiler Tubes and Sheets," will be presented by the Chairman of the Sub-Committee, Mr. R. E. Coughlan.

Mr. R. E. Coughlan (Chicago & Northwestern):—The report of this Sub-Committee appears in Bulletin 383, Appendix B, page 399, and deals this year with the particular trouble of cracking of boiler plates along the riveted seams below the water line of the boiler and the breaking off of the rivet heads.

This peculiar type of boiler cracking, referred to as "Embrittlement" or as it is sometimes called "Caustic Embrittlement," is one of the important problems of the Railway Water Engineers at the present time.

The trouble first came to the attention of boiler operators about 24 years ago in one of the boilers of a stationary power plant in Illinois. Since that time it has extended to various sections of the country as well as to various countries in Europe. Not only the stationary boilers in power plants but locomotive boilers as well appear to be affected.

A vast amount of research is being done on the problem, including the study of design, construction and operation of boilers so affected, as well as the characteristics of the feedwater used. Up to the present time, there was a considerable variance in the findings and reports of these research workers as to the specific cause of this trouble.

While the definite cause of this trouble is as yet unknown, several methods of its prevention have been developed. These remedies are given on page 400 of this report. Inasmuch as there is so much difference in opinions of those well informed in the various phases of this problem, this report is presented as a progress report and for information.

The President:—This is one of the particular matters for which the Board of Direction and your administrative officers are hopeful they may soon be able to secure financial aid for the Committee to enable it to extend its research work and thereby enlarge its usefulness. The future work of this Sub-Committee will be watched with increasing interest by the Association.

Chairman R. C. Bardwell:—In connection with the remarks of our President, I might mention that this subject is being given very serious consideration and study by the Joint Committee composed of the following Associations: American Society of Mechanical Engineers, American Society for Testing Materials, American Water Works Association, the Edison Institute, American Boiler Manufacturers' Association, the United States Navy Experiment Station, and the United States Bureau of Mines. The research work is being conducted in the New Brunswick, New Jersey, Experiment Station under the direction of Dr. W. C. Schroeder. The work has not yet progressed to the point where the solution is evident and it is hoped that funds will be available for continuing this work, and if so, we will have further progress to report next year.

The Committee desires to report progress on Subject 5, "Value of Water Treatment." Considerable data has been gathered on the subject by the Chairman of the Sub-Committee, Mr. C. P. Richardson, but it is desired to withhold the report until next year.

The report on Subject 6, "Types of Lime and Soda Ash Equipment," will be presented by the Chairman, Mr. H. E. Silcox.

Mr. H. E. Silcox (Chesapeake & Ohio):—The report of the Sub-Committee on Assignment 6, "Types of Lime and Soda Ash Equipment in Treated Water," is presented in Bulletin 383 as Appendix C, pages 400 to 406 inclusive.

This report covers the development of equipment used in complete treatment of water for boiler purposes. It also describes the types of mechanical devices for introducing reagents in direct proportion to the flow of water to be treated, calling attention to their adaptability in plants of various capacities. This report is submitted as information.

The President:—It will be so received.

Chairman R. C. Bardwell:—The Committee desires to report progress on Subject 8, drinking water sanitary regulations, as no new information developed during the past year. It is recommended that this subject be continued in order that the Association may be kept advised of such changes as they are developed.

The final report on Subject 9, "Water Conditions Affecting the Extension of Locomotive Washout Periods," will be presented by the Chairman of the Sub-Committee, Mr. J. B. Wesley.

Mr. J. B. Wesley (Missouri Pacific): It is my privilege to present the report of Sub-Committee 9 on behalf of the Water Service Committee, on the subject of "Water Conditions Affecting the Extension of Locomotive Washout Periods."

In our study on this subject we find that there are five boiler conditions producable by water that adversely affect the maintenance and the operation of locomotives. Of these five boiler conditions, we find that three of them are not corrected nor prevented by boiler washing. The other two of the five, the accumulation of mud, or sludge, and foaming, can be prevented by boiler washing if it is done with sufficient frequency, but these are the only conditions produced in boilers by water that have any effect whatever on the extension of the boiler washout periods.

In this report extended consideration has been given to handling and controlling these two conditions, full consideration being given to water conditions that cause these things in the boiler. It is found that while the frequent washing process can largely prevent foaming and the accumulation of mud, equivalent results in this regard can be secured by systematic use of boiler blowoff cock, and this second process of maintaining a satisfactory boiler condition in the boiler is found to be no more expensive than the washing process, while it does bring to the road benefits that cannot be secured by the washing method of control. At the same time, most of the cracked sheets, broken stays and conditions produced by frequent washing are avoided. In other words, better boiler and firebox conditions are obtained.

The report discusses different arrangements for boiler blowing, including types of blowoff cocks, mufflers, blowdown facilities for terminals, and the instruments used to determine the condition of water inside the boiler. The disadvantages and the objections to boiler blowing are discussed. These are shown to be less serious than they are sometimes thought to be.

After a close study of water conditions affecting the extension of boiler washout periods, we conclude that by systematic boiler blowing on line of road and at terminals the boilers can be maintained in a satisfactory operating condition for an indefinite period of time, so far as the water conditions affect the situation. If the boilers are systematically and satisfactorily blown, the only water condition that can justify and require a washout is that of mud or sludge so heavy as to subject the firebox sheets to the hazard of being burned. Under normal water conditions the mechanical condition of the boiler and the government requirement of a washout every thirty days are the factors that determine the length of the locomotive boiler washout period.

The President:—Gentlemen, you have heard the report of the Sub-Committee, which they recommend as a final report on the subject. The Committee further recommends that its report be accepted as information. No action is therefore necessary by the convention. The Board of Direction will in due course give consideration to their recommendation with respect to the disposition of the assignment.

Mr. D. A. Steel (Railway Age):—Since the Chairman has taken occasion to compliment the Committee which prepared the report on the embrittlement studies, I think it is in order to compliment the Committee that prepared this report.

I have been observing the progress of the Water Committee's work and reading its reports for fifteen years, and this, to my mind, is one of the most informative reports that has been presented. It is particularly interesting at this time because it has to do with one of the important developments in water service—that of obtaining satisfactory water conditions for locomotive operation without terminal delays and expense. I have some questions to raise, however. As I understand it, the idea is to eliminate, as far as possible, the washout. It does not seem to me that enough distinction has been made between the washout and the water change. In the old days it was customary to washout frequently. More frequently, the water was merely changed. The washout requires the removal of plugs, and the water change simply involves dumping the old water and replacing it with new.

I also wonder if the Committee is not a little over-enthusiastic at this moment regarding the ability to operate engines with so little boiler washing. I understand the government prescribes a 30-day limit beyond which a locomotive may not be operated without a washout, regardless of how well the water has been treated and how well the engine has been handled on the road by blowing down. I also understand that the Committee does not advocate changing the government's requirements. At the same time, there is nothing in the report as to the value of a washout in permitting a visual inspection of the interior of the boiler. It is naturally assumed that to wash out only once a month, the boiler operation is being carefully supervised and the water is well treated. We must be careful not to go too rapidly and too enthusiastically in discarding long-established feedwater practices until we have eliminated the possibility of trouble that arises from some unforeseen letdown in supervision, resulting often from conditions over which the water forces may have no control, or some change in the water condition unknown to those in charge of water work. Frequent water changes and frequent washouts that allow a visual inspection of the inside of the boiler can often be continued without destroying the benefits of better blowing down of the boilers on the road.

While, therefore, the report reveals remarkable progress in an important field of water work, we should constantly have in mind the importance of proceeding only as rapidly as we can coordinate all the various forces and factors involved in securing the correct results and providing adequate security against locomotive failures on line, and locomotive accidents.

The President:—I understand the function of this Committee is to find out what to do and then go and do it. They appear to have done a pretty good job.

Mr. L. S. Rose (Peoria & Eastern):—I do not think the Committee needs any defense. They are all right.

The thing we ought to do is to get the Committee to extend the 30 days on boiler washing period, or get the government to extend the time. If we followed what the Committee recommends, we would not have to wash the boilers more than once a month and they would all be clean, and we would not have to change the water, either. The only thing I should like to know is how the Committee gets a systematic blowing.

Chairman R. C. Bardwell:—I believe I can answer that for the Committee by saying that it is necessary to obtain the cooperation of the General Managers and the Operating Officials to arrange for the recommended blowdown schedules being followed by the road crews and the terminal forces.

Mr. L. S. Rose:—Well, do you work the General Managers day and night in getting after the engineers to blow their boilers? If you do that, you would have to wash the boilers but once a month, when the government tells you, and you would not have any bad or loose or dirty sidesheets, I know that. I think this Committee's report is all right. The only difficulty is in getting that systematic blowing. Have you ever tried an automatic blowoff?

Mr. J. B. Wesley (Missouri Pacific):—Yes, sir.

Mr. L. S. Rose:—Which will automatically blow the boiler? I think the hardest thing is in getting the systematic blowing.

The President:—Thank you, Mr. Rose. If there is no further discussion, the report will be accepted as information.

Chairman R. C. Bardwell:—Your Committee desires to report progress on Subject 10, "Clarification and Disinfection of Small Railway Drinking Water Supply." Considerable information on this subject has been collected by the Chairman of the Sub-Committee, Mr. W. P. Hale, and he hopes to have a final report next year.

That concludes the report of Committee XIII.

The President:—Mr. Bardwell, I wish to thank you and the Committee for your excellent report. You are now excused with the thanks of the convention (Applause).

DISCUSSION ON ELECTRICITY

(For Report, see pp. 557–558)

Mr. G. I. Wright (Reading):—Inasmuch as the annual meeting of the Committee of Direction of the Electrical Section is held in the fall, this report really covers the year 1934. It has been partly brought up to date to cover the year 1935.

Your Committee was instructed to (a) keep the Association informed of developments in the application of electricity to railway service, supplemented with list and reference by number of adopted specifications, design and principles of practice.

Power Supply.—During the year 1934 no important additions were made to the Central Station capacity of the country, the total additions amounting to only 95,000 KW. Preparations, however, were being made for large additions in 1935 which are estimated to exceed 500,000 KW. The people in the industry that I have talked to feel that the expansion in central station power is going to be very much greater during the next few years to make up for the halt in that development during the last years of the depression. The principal steam addition provided for was the 165,000 KW. unit at Richmond Station of the Philadelphia Electric Company. The diesel-electric stationary plants installed in 1934 were confined to small units not normally recorded with the major public utility power plants.

The report of the United State Geological Survey of April 1935 gives the total power produced for public use in 1934 as 91,150 million KW. hours, 62 per cent of which was produced by thermal plants and 38 per cent by hydro-plants. The equivalent coal consumed in the thermal plants was 41.25 million tons, giving a rate of 1.45 lb. of coal per KW. hour, which is a slight improvement over the 1933 rate of 1.47 lb. per KW. hour and 45 per cent of the 1919 rate.

The Federal Power Commission's "National Power Survey" was continued throughout 1934. This report supplies very complete data on the electric supply industry, together with a most valuable survey of the fuel and water power resources of the country. The report may be of importance to railroads and industries interested in the use of large amounts of electric power. Should rail traffic density be at all favorable in the Tennessee Valley, Boulder Dam, Columbia Valley or Passamaquoddy Districts, the attractive power rates shortly available at these points will very materially enhance the economic possibilities of electric traction.

Interest continues in the application of diesel power to railroad service. Orders were placed for a large number of 600 hp. diesel-electric yard switching locomotives, with indications of a very extended use of this type of motive power. Studies were carried out in the application of diesel-electric locomotives to yard transfer work which resulted in contracts being let for three units with power plants varying from 1800 hp. to 2000 hp. Main line locomotive units of 1800 hp. were designed, resulting in some preliminary orders being placed early in 1935. These locomotives are now in revenue service. The most spectacular diesel-electric railroad application in this country is probably the Burlington Zephyr type trains. The first of these trains, four of which are now in service on the Burlington, went into revenue service on November 11, 1934, and has run in a period slightly over 12 months 187,000 revenue miles.

No new railroad electrification projects were started in 1934. The Pennsylvania continued their electrification program from New York to Washington and actually initiated this electric service on January 28, 1935. Freight and passenger service between New York and Potomac Yard, Washington, and between New York and Paoli is now operated electrically.

Clearances.—Attention was called to the servicing of equipment along right-of-way for air-conditioning and pre-cooling of cars. The report contains a table giving the characteristics of outside power supply for pre-cooling of air-conditioned cars on various railroads where facilities have been installed and where data has been published.

The subject of Overhead Clearance Lines for Permanent Way Structures on Electrified Railways received considerable additional study during the year. The replies to a questionnaire sent to thirty-one electrified roads were studied and twenty railroads selected as having typical steam railroad electrifications on which it was thought recommendations should be based. The replies from the twenty railroads were tabulated, corrected by the railroads and included in the report. They constitute an interesting exhibit.

Based on this summary, a series of recommendations for overhead clearance lines for permanent way on electrified railways were prepared and submitted tentatively.

Illumination.—Under this heading, the recent developments in incandescent lamps, locomotive and train lighting lamps, and gaseous conductor lamps were reported on in detail. New types of lamps have been developed fundamentally different from our present lamps and are being first applied to street and highway lighting, and a Committee is watching these applications and feels that the experience gained from them can be used to decide whether these types of lamps will be advantageous for yard lighting or other railroad uses.

A comprehensive report is made on car lighting, due to problems arising out of the advent of the high-speed, streamlined trains, most of which have lower heights of the car ceilings and many of which used indirect or semi-indirect lighting.

Application of Corrosion-Resisting Materials to Railway Electrical Construction.—This is an extension of some tests that were initiated about eight years ago, and a study of all metals applicable for use in overhead electric construction is one of the studies in the Committee's activity that the Electrical Section has done that I think falls clearly in the field of research about which we hear so much.

The samples installed in Hemphill Tunnel on the Norfolk & Western Railway were inspected by members of the Committee in 1935. The samples of aluminum strand had become so badly corroded that the wires untwisted and caused a ground, which burned the messenger apart and the samples fell down. The aluminum trolley clips were badly corroded. All the other samples showed considerable corrosion, but were in a safe condition. The samples in Hemphill Tunnel will be taken down in January, 1936, and weighed. A final report on these samples will be made this year.

Progress reports were also presented on the following subjects: Electrolysis, Overhead Transmission Line and Catenary Construction, Standardization of Apparatus and Materials, Electric Heating and Welding, Protection of Oil Sidings, Specifications for Track and Third Rail Bonds, Design of Indoor and Outdoor Substations, High Tension Cables, and Application of Motors.

Bibliography on Application of Electricity to Railways.—This valuable bibliography, which includes periodical articles only, is prepared annually, covering the period from July to June. In its preparation the periodicals listed have been examined; these periodicals may be seen in the libraries indicated. The references are arranged in three large groups. Within these, they are arranged under subjects, first, and then in chronological order. An index provides references to the articles by any particular author.

That concludes the report of the Committee, which is simply a resumé and the tabulation of information for the benefit of members of the Association. I thank you.

The President:—The report of Committee XVIII will be received as information and no action is necessary by the convention. Mr. Wright, I want to thank you and your Committee, and they are now excused with the thanks of the convention (Applause).

DISCUSSION ON ECONOMICS OF RAILWAY OPERATION

(For Report, see pp. 535–556)

Mr. M. F. Mannion (Bessemer & Lake Erie):—The report of Committee XXI—Economics of Railway Operation, will be found on pages 535 to 556 inclusive of Bulletin 383.

The Committee reports progress on six subjects, 2, 3, 4, 5, 8 and 9. With regard to these assignments, on which progress only is reported, the Committee wishes to advise that much valuable data has been accumulated, and work of considerable importance has been accomplished, which it is hoped will shortly be put in shape for the benefit of the Association.

Reports are submitted on three subjects, 1, 6 and 7. The report on Subject 1, Revision of Manual, will be presented by Mr. J. M. Farrin, Chairman of the Sub-Committee.

Mr. J. M. Farrin (Illinois Central):—The report of Sub-Committee 1, Revision of Manual, will be found under Appendix A, page 536, Bulletin 383, January 1936.

The Sub-Committee studied the subject-matter developed by Committee XXI now in the Manual with the view of deleting those portions now obsolescent or unnecessary and reducing the remaining portions as much as possible consistent with clarity. Our idea is that the subject-matter in the Manual should be complete enough for applications to practical problems without reference to the Association's Proceedings, but not necessarily in complete detail showing development.

Accordingly, we recommend that the subject-matter now appearing on page 1403 of the Manual, "A Formula or Method of Calculating the Cost of Moving Freight Traffic," be deleted.

I move that the subject-matter on page 1403 of the Manual, "A Formula or Method of Calculating the Cost of Moving Freight Traffic," be deleted.

The President:—It is moved and seconded that the recommendations of the Committee be accepted and that the material now appearing in the Manual be deleted.

(The question was put to vote and carried.)

Mr. J. M. Farrin (Illinois Central):—The subject-matter now appearing on page 1421 of the Manual, "Feasibility and Economy of Through Routing of Solid Trains and its Effect upon the Capacity of Terminals," to remain as at present.

The President:—Mr. Farrin, I suggest that you proceed with your report unless or until some question is asked or objection raised. A motion will then be in order for some form of action on the report in its entirety.

Mr. J. M. Farrin:—"Operation of Trains Against the Current of Traffic on Multiple Track," shown on page 1421 of the Manual. No change is recommended.

Subject-matter now on page 1421 in the Manual, "Method for the Determination of Proper Allowances for Maintenance of Way Expenses due to Increased Use and Increased Investment," to be replaced by subject-matter as shown under A-1, page 536, Bulletin 383, January 1936.

I move that the Manual be changed as recommended.

(The motion was put to vote and carried.)

Mr. J. M. Farrin:—The subject-matter now on page 1435 of the Manual, "The Cost of Stopping and Starting Trains," to be replaced by the subject-matter shown under A-2, page 541, Bulletin 383, January 1936.

I move that the Manual be changed as recommended.

(The motion was put to vote and carried.)

Mr. J. M. Farrin:—The subject-matter now on page 1443 of the Manual, "Formula for Determining Comparative Economies of Flat and Hump Switching," delete the notes only, leaving the formula remain as at present.

I move that the Manual be changed accordingly.

(The motion was put to vote and carried.)

Mr. J. M. Farrin (Illinois Central):—Subject-matter on page 1447 of the Manual, "Comparative Freight Train Performance Charts," to remain as at present.

That completes the entire revision of the Manual so far as Committee XXI is concerned.

Vice-Chairman M. F. Mannion:—The report on Subject 6, "Effect of Volume of Traffic on Railway Operating Expenses," will be presented by Mr. Radspinner.

Mr. W. A. Radspinner (Chesapeake & Ohio):—On page 544, Bulletin 383, can be found, under Appendix B, the report of the Sub-Committee on the Effect of Volume of Traffic on Railway Operating Expenses.

The study covers a period of four years, 1928 to 1932 inclusive. It has taken into consideration the actual gross expenses for each primary account that is influenced by changes in traffic density.

The data was assembled by districts and there was found such a variation in general characteristics that each district has been presented separately.

The method may be used to determine the expense under conditions of either increased or decreased traffic as compared with a base period, but it should be used with caution. It will not yield consistent results either in the case of a small property or sudden temporary changes in traffic density.

This report is submitted as information.

The President:—It will be so received.

Vice-Chairman M. F. Mannion:—The report on Subject 7, "Operation with Reduced Number of Main Tracks," is shown as Appendix C on pages 548 to 556 inclusive. This report is a study of the effect on operating and maintenance expenses of converting double track to single track. It shows a comparison of maintenance and operating costs for comparative years.

Two studies are reported on, one covering a 32-mile conversion and the other a 28-mile conversion. Different operating, track and signal conditions are contained in each study. On page 548 is shown the traffic and operating methods for the 32-mile study.

Fig. 1, page 555, shows the original track plan, and Fig. 2 shows the track plan for single track operation. The changes in original double track facilities are listed on page 549. Also, on page 549 is shown the annual reduction in costs resulting from single-track operation.

These savings are figured on two bases: First, under the deferred maintenance condition which existed when the change was put into effect. The net estimated reduction in annual cost under deferred maintenance amounts to $31,310.

Second, under normal maintenance conditions. Under such conditions, the estimated reduction in annual cost is $52,770.

The maintenance savings are divided into two classes: First, savings in ordinary routine repairs, day-by-day renewals, partial replacements and adjustments; and second, extraordinary repairs, those made periodically at longer intervals, such as rail, tie, bridge, and ballast renewals.

On page 550 is shown as information the expenditures postponed by single track operation. The actual cost of making the necessary track changes and retirements, together with salvage and cost of removal, are shown on page 550, the cash expenditure amounted to $14,460; the estimated cost to remove track, $13,000; salvage, $162,674. The result was a net credit of $135,214.

At the bottom of page 550 and at the top of page 551 is shown a summary of cost and savings.

On the basis of present-day costs, the annual reduction in cost of maintenance and operation of $13,000 on a cash expenditure of $14,460, resulted in a return of 217 per cent on the cash expenditure, and on a normal maintenance basis this figure would be 365 per cent.

The same procedure is followed for the 28-mile study, on pages 551 to 554. The summary of estimated savings is shown on page 554. This study, on the basis of deferred maintenance, resulted in a 225 per cent return on the cash expenditures, and on the basis of normal maintenance resulted in a 271 per cent return on the cash expenditure.

The ability and economy of handling a future increase in traffic with single-track operation was studied. This study revealed that traffic equal to the heaviest traffic in recent years (1921–1931) could be more economically handled with single-track operation and improved signal facilities, such as automatic block or C.T.C., than with double-track operation.

The conclusions of the report are shown on page 556: "Where the volume and distribution of traffic on double track has decreased to such an extent that the expense of double-track operation cannot be justified, the economic advantage of converting all or a portion of the double track to single track should be considered. Further, when consideration is given to the progress made in handling increased traffic by modern signal facilities, the economy in maintenance, and the safety of operation, the necessity to return to double track for the efficient operation of trains becomes more remote."

Your Committee recommends that this report be accepted as information.

The President:—Thank you, Mr. Mannion.

I am sure the convention needs no word from me to appreciate that while its work has been presented in the form of progress reports, this Committee is in reality laying the foundation for constructive work of great value to this Association and the engineering profession generally, the results of which I feel confident will ultimately prove of equal importance to the general public as well as the railroads.

I desire to congratulate this Committee. They are doing excellent work and are now excused with the thanks of the convention (Applause).

DISCUSSION ON ECONOMICS OF RAILWAY LABOR

(For Report, see pp. 235–264)

Mr. F. S. Schwinn (Missouri Pacific):—The report of Committee XXII—Economics of Railway Labor, will be found in Bulletin 382, page 235. Although none of the subjects assigned to this Committee for the past year has been completed, the Sub-Committees have undertaken a large amount of study and research and several extensive progress reports are presented.

For Subject 1, Revision of Manual, this Committee presented a complete revision of its material at the last convention, and as this was approved by the Association and has met the requirements of the editor of the Manual, no further action was required during the past year.

For Subject 2, "Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work," Subject 7, "Economies in track labor to be effected in the maintenance of joints by welding and the use of reformed bars," and Subject 9, "Comparative costs of maintaining track on various kinds and depths of ballast," your Committee presents brief statements of progress as given in Appendices A, E and G.

We are again unprepared to make any report at this time on Subject 6, "Economies in labor to be effected through increased capital expenditures."

Subject 3, "Economics of methods of weed killing," was studied by a Sub-Committee of which Mr. Knowles is Chairman. The study developed into an exhaustive report which, because of the importance of weed control, should be very helpful. I will ask Mr. Knowles to please present this report.

Mr. C. R. Knowles (Illinois Central):—The report of Sub-Committee 3, "Economics of Methods of Weed Killing," appears on page 236. While this is quite a lengthy report, it is presented as a progress report and covers only that portion of the right-of-way within the limits of the roadbed. It is the desire of the Committee to continue the study with a report upon the economics of weed killing as affecting the balance of the right-of-way.

This report is submitted as information.

The President:—It will be accepted as information.

Chairman F. S. Schwinn:—Subject 5, "Out-of-face renewal of track in view of the increasing life of basic units of track construction," has been undertaken with the intent of first developing European practice. Some very interesting information has been gathered and I will ask Mr. O'Rourke, Chairman of the Sub-Committee, to please present this report.

Mr. G. M. O'Rourke (Illinois Central):—Your Committee was instructed to ascertain practices on American railways and those of foreign countries in renewing the track structure in its entirety and to determine what, if any, economies in labor are effected by such maintenance practice.

The report appears under Appendix D, near the bottom of page 254, Bulletin 382. We secured information concerning practices in Germany and England and information descriptive of the manner in which the work was done; very little, if any, concerning the French practice, and nothing at all from other foreign countries.

Maintenance and renewal practice in Germany is described commencing at the top of page 256, with illustrations. The practices in England are described commencing at the bottom of page 258.

Our conclusions are: "According to the investigations made by the Committee, the principal difference between American and European practice lies in the matter of out-of-face renewals of ties and out-of-face surfacing to replace spot surfacing. For many years American railways have replaced rail and fastenings out-of-face as is done in the European countries. It is the opinion of the Committee that out-of-face renewals of ties in European countries has largely been made economical and practical as a result of the longer tie life and control of mechanical wear secured by use of relatively large tie plates, independently and securely fastened to the ties. It is further the opinion of the Committee that the practice of out-of-face surfacing maintenance is made practical and economical in these countries as a result of the well-drained and compacted roadbed, and of the high relative strength of track structure compared to the wheel loadings. The Committee wishes to draw attention, in this connection, to the increasing practice in recent years on many American railways of performing out-of-face surfacing every three to four years on heavy track sections, making all tie renewals that would be required prior to the next surfacing period."

Recommendations: "Your Committee recommends the subject be continued for study of relative labor economies of American and European practices; this report to be received as information."

The President:—It will be so received.

Chairman F. S. Schwinn:—Subject 4, "Gang organization and methods of performing the more common tasks of maintenance of way work," has been studied from the standpoint of labor requirements for rehabilitation of rail ends by gas welding. These requirements have been carefully analyzed by the Sub-Committee and the recommendations should prove of material assistance.

In the absence of the Sub-Committee Chairman, Mr. Kirby, I will ask Mr. Howson to please present the Committee's report.

Mr. Elmer T. Howson (Railway Age):—In reporting on this broad assignment the Committee has taken the subject of welding up for consideration this year. Welding has become of rapidly increasing importance to the railways in view of the growing proportion of their maintenance budgets that is being devoted to the purpose. As with all expenditures, economy makes prerequisite a definite plan for the conduct of that work.

After outlining the factors entering into the welding program, the Committee has set up organizations to do the work with varying degrees of completeness, which organizations are presented on pages 252 and 253 of the report. From these various organizations, the Committee has drawn certain conclusions, which, appearing on page 254, read very briefly.

The Committee recommends that this report be received as information and the subject be reassigned for further study.

The President:—It will be so received.

Chairman F. S. Schwinn:—Subject 8, "Effects of recent developments in maintenance of way practices on gang organization," has been developed with the view of bringing to date previous reports on this subject. This has been ably done by the Sub-Committee, and I will ask Mr. Magee, Sub-Committee Chairman, to present his report.

Mr. G. M. Magee (Kansas City Southern):—The report on this assignment appears on pages 261 to 264 of Bulletin 382. The purpose of the assignment was to survey changes in methods of gang organization for proper maintenance work, which changes have resulted from an improved track structure in developing of labor-saving devices. Three previous reports on this assignment have been presented to the Association by the Committee. In this year's report the information given in preceding reports has been brought up to date and in addition information has been given for railways not included in previous reports which have made marked changes in their maintenance organization since that time.

It is the conclusion of the Committee that "improvements made in the track structure during the years from 1922 to 1930 have reduced the routine maintenance work and permit the delegation of heavy maintenance in a systematic manner to specialized gangs fully equipped with labor-saving devices with resulting economies."

The Committee recommends that this report be received as information and the assignment be continued for further study.

Mr. G. M. Cornell (Chesapeake & Ohio):—In connection with this report, I would like to ask the Committee one question. In several places the report states that railroads have recognized and realized improved efficiency. My understanding is that that would mean the performance of a given amount of work, of a given quality, at a reduction in cost. I can see how we can measure quantity, and I can see how we can measure cost, including labor and equipment and interest on investment, but I am interested in the matter of measuring quality. In any of these reports which you have received have you any definite engineering data in connection with quality?

Mr. G. M. Magee:—On this particular assignment, every subject must be handled or at least the Committee felt it should be handled more by asking the engineering officers of the various railroads their opinions, based on their experience in these kinds of matters. The Committee endeavors to present here merely a report of their opinions.

I do not know whether the matter was brought out entirely in the report, or whether that question was exactly put to them, but as a general rule, on the questions put to them they indicated in most cases that they felt the work was not only less expensive but also more satisfactory.

Mr. G. M. Cornell:—You do not know of any case in which, for instance, they have used inspection cars equipped with various devices for the measurement of the quality of work, say for surfacing?

Mr. G. M. Magee:—I do not. There may have been some used, but that was not brought out.

Mr. G. M. Cornell:—So far as this report on efficiency is concerned, the quality of work is as determined by the engineering officers, that is, their opinion of quality?

Mr. G. M. Magee:—That is, their opinion. That is the thing that is determining.

The President:—The last speaker has made some timely suggestions. If there are no further questions, the report will be received as information.

Chairman F. S. Schwinn:—That concludes the report of the Committee.

The President:—It is perhaps needless to point out to the convention that the trend of events in railway transportation appears now to lie largely in the ability of our railways to safely and satisfactorily get over the road, not only at greatly increased speeds but at speeds that shall also be relatively uniform and consistently maintained. These requirements will in turn introduce many new and novel roadway problems, not only in the economics of railway operation and maintenance but in location and coordination as well. The solution of these problems will require vision, versatility, and a high degree of engineering and economic research. This Association has accepted this trend, as a careful study of the work of many of its committees will show, and this is especially true of the Committee on Economics of Railway Labor, which is engaged on work of great constructive value to the railroads. Mr. Schwinn, your Committee is now dismissed with the thanks of the convention (Applause).

DISCUSSION ON SIGNALS AND INTERLOCKING

(For Report, see pp. 65–68.)

Mr. C. H. Tillett (Canadian National):—The report is found on page 65 of Bulletin 381. It presents the noteworthy advances in the art of signaling during the last year and a resumé of the activities of the Signal Section of the AAR. If there is any question the Committee can answer, they will be glad to do so. If not, I move we accept this as information by the Association.

The President:—Gentlemen, the Chairman asks that the report of Committee X be accepted as information. It will be so accepted. Mr. Tillett, your Committee is excused with the thanks of the convention (Applause).

DISCUSSION ON BALLAST

(For Report, see pp. 559–576)

Mr. A. D. Kennedy (Atchison, Topeka & Santa Fe):—The report of the Ballast Committee is in Bulletin 384. The assignment of your Committee this year is confined largely to the revision of the Manual and in covering this work the Committee has reviewed the material in the Manual and is coming before you with certain revisions which are brought about, to some extent, by obsolescence. Other matter is recommended to be deleted from the Manual for the reason that the matter does not any longer come under the chapter on Ballast.

The other subject of the Committee is the preparation of Specifications for Blast Furnace Ballast. There is nothing that I can say further in a general way about this report and I will ask Mr. Dunn, Vice-Chairman of the Committee, and Chairman of the Sub-Committee on Revision of the Manual, to present the report.

Mr. M. I. Dunn, Jr. (Chesapeake & Ohio):—The Committee on Revision of the Manual has a number of revisions to offer at this time. For reasons brought out by Mr. Kennedy, I do not think it is necessary to go into the particulars on each revision unless we have some discussion from the floor.

The first recommendation is that the definition of "Spot Board" be withdrawn from the Ballast Section and referred to the Committee on Outline of Work. We move that this withdrawal be made.

The President:—The Committee on Ballast recommends and a motion has been made that certain data now appearing in the Manual be withdrawn.

(The question was put to vote and carried.)

Mr. M. I. Dunn, Jr.:—On page 93 is found a definition of "Chert." Our present definition of "Chert" is "An impure flint or horn stone." This is an incorrect definition, and we propose a revision as follows: "Chert.—A compact, flintlike, siliceous rock formed of micro-granular silica of organic or precipitated origin." This is a much better scientific definition. We move that the change be made.

We propose the withdrawal of the definition of "Burnt Clay," for the reason that this is no longer being used as ballast for ballast renewals. There is a small amount, so far as that is concerned, still in service, but no burnt clay ballast is being put into service.

On page 93 we propose to improve the definition of "Disintegrated Granite."

Page 94 of the Manual, definition of "Gravel." At the present time we have three definitions: "(a) Pit-run gravel; (b) screen gravel; and (c) washed gravel," with "washed gravel" having been withdrawn in 1930, and a "prepared gravel" specification and definition adopted in 1930.

The proposed forms are shown at the bottom of page 559 of the Bulletin.

On page 94 we have a definition of "Sand," which we propose to revise to bring it in line with our proposed specifications on prepared gravel ballast. In connection with adoption of the square opening sieve, the definition does not greatly change the present definition for sand except to bring it in line.

Definition of "Slag," revision as follows: "Slag.—A non-metallic fused product resulting from the reduction of ores in furnaces."

Definition of "Slag (Blast Furnace).—A slag consisting essentially of silicates and alumino-silicates of lime, which is developed simultaneously with iron in blast furnaces." That is a new definition.

The definition of "Stone" we propose to revise to read as follows: "Crushed Stone.—The product resulting from the artificial crushing of rocks, boulders or large cobblestones, substantially all faces of which have been produced by the crushing operation."

We move the adoption of these revisions as shown on pages 559 and 560, revisions (1) to (10) inclusive.

The President:—The Committee on Ballast moves the adoption of these definitions as read by the Chairman.

(The question was put to vote and carried.)

Mr. E. R. Lewis (Michigan Central):—I have no criticism to offer on any of these definitions, but several of these words are in Webster's dictionary. Therefore our definitions will be superfluous. It is my understanding that committees are not supposed to present definitions for words that are in the dictionary.

Mr. C. W. Baldridge (Santa Fe):—It seems to me that there has been considerable misunderstanding in regard to our publication of or adoption of definitions. It is very true that a great many words are defined in the dictionary. There is one word defined by this Association which I looked up this year, I do not know now what it was, but Webster's dictionary gives eight different meanings for it. Very frequently we want to limit the meaning and for that reason it is very appropriate that we adopt definitions in order to limit, in some cases, the meaning of a word that we want it to convey when used in our work.

Mr. E. R. Lewis:—I am very glad to hear Mr. Baldridge's discussion because that is what I wanted to bring out: Where are we going to draw the line?

Mr. M. I. Dunn, Jr.:—The revisions are not new material. The definitions exist at the present time in the Manual. They are merely improvements to bring the definitions that we have up to date. We do not propose to eliminate, we do not propose to add; we are merely proposing to improve.

The President:—The motion is on the adoption of the recommendations of the Committee.

(The question was put to vote and carried.)

Mr. M. I. Dunn, Jr.:—Page 560, "Choice of Ballast." We propose revision of the material now appearing on page 94 of the Manual. A good deal of the material now appearing is superfluous and the proposed form, we feel, is clearer and more concise. We move its adoption.

The President:—It has been duly moved that the recommendations of the Committee be adopted.

(The motion was put to vote and carried.)

Chairman A. D. Kennedy:—The next subject is the adoption of "Specifications for Prepared Gravel Ballast." We will ask Mr. Stanton Walker, formerly Chairman of the

Sub-Committee, who had this matter in hand, to come to the platform to present this part of the program.

Mr. Stanton Walker (National Sand & Gravel Association):—The revised "Specifications for Prepared Gravel Ballast" proposed at this time do not differ in principle from those already approved by the Association and published in Bulletin 337 under date of July, 1931. They do involve, however, some revisions believed to be helpful, and some important additions. The revisions consist of, first, a change in the method of stating the gradings, and second, certain changes in the gradings. The change in the method of stating the grading comes from a substitution of square mesh testing sieves for the screens with round openings previously used. It should be emphasized that this change does not make it necessary to modify plant practices—it affects only the method of testing the finished product.

The change has been made in recognition of the trend in the practice of testing engineers toward the substitution of square sieves for round screens. The reasons for this trend are many and probably do not require discussion at this time. One of the more obvious reasons comes from the fact that screens with round openings are readily available only in the coarser sizes and are therefore applicable only to tests of coarse aggregate. In testing the finer sizes it has been necessary to use screens with square openings. The difficulties involved in studying a complete grain size analysis of a combined material when a part of it is tested through round openings and a part through square openings should be self-evident.

The changes in gradings recommended are illustrated in the diagrams which accompany the complete report in the February 1936 Bulletin of the Association.

Only one important change has been made and that is in connection with the gravel ballast containing less than 20 per cent of crushed particles. It has been called to the attention of the Committee that the existing specifications for uncrushed gravel ballast is inconsistent with generally accepted practices. The point has been made that stopping the grading at the No. 10 sieve, as is the case with the specification now on the books of the Association, does not provide suitably graded fine material to insure stability. The Committee has therefore changed the grading for this class of material to make it consist of a mixture of gravel and of coarse sand. It is believed that this change will improve the stability of uncrushed gravel ballast and bring the requirement more into line with current practice.

In the case of the two remaining classes of gravel ballast, the changes are not great. The classification requiring from 21 to 40 per cent of crushed particles has not been changed more than has seemed consistent with the translation from round openings to square openings in testing sieves. For the material with 41 per cent or more of crushed particles the proportion of finer sizes has been increased somewhat in the interest of stability. In all cases limitations on dust, subsequently referred to have been included to insure a clean ballast.

There has been a slight change in the top size for all three classifications. The existing specifications limit the top size to that which will pass a 1½ inch round opening—approximately equivalent to a 1¼ inch square opening. In the interest of standardization the top size in the revised specification has been made that of a particle which will pass a 1½ inch square opening—approximately equivalent to a 1¾ inch round opening. The Committee does not believe that this one-quarter inch addition in top size has any important effect on the quality of the material but it does believe that it materially aids standardization.

It should be pointed out that these gradings as revised have been incorporated in a group of standard sizes applicable to crushed stone and slag as well as sand and gravel, recommended jointly by the National Crushed Stone Association, the National Slag Association and the National Sand and Gravel Association, which are being used as a basis for a simplified practice program carried on in cooperation with the Division of Simplified Practice of the National Bureau of Standards. That Division has distributed these recommended standard sizes, which include sizes for all common uses of mineral aggregates in the construction field, to the several railroads.

The preceding outlines the changes of more than an editorial nature which have been made in the existing specification. Some important additions have also been made. The existing specification includes no definite requirements for deleterious substances, soundness and resistance to abrasion, nor does it include test methods for measuring such characteristics. The Committee has long been charged with the problem of developing information on these factors and at previous annual meetings has presented considerable data on them.

The revised specification includes definite limits on material finer than the 200-mesh sieve, on soft and friable particles, and on clay lumps, and refers to recognized standard test methods for their determination. The revised specification also provides methods for measuring the soundness and resistance to abrasion and furnishes suggestions on which to base specified limits for these factors. The new specification also outlines a basis for the determination of the percentage of crushed particles.

Chairman A. D. Kennedy:—Mr. Walker has given you a resumé of the specifications as presented. I move that they be adopted in lieu of the specifications which appear in Bulletin 337 and as now adopted by the Association.

Mr. C. W. Baldridge:—This set of specification brings up again a subject we had up yesterday, of quoting, or referring, rather, to other specifications without repeating them. At the bottom of page 560 we have a note which refers to the ASTM specifications. Again, on page 561, Article 5 refers to the ASTM specifications. Then, (b) of Article 4 refers to the Deval abrasion test, upon which you have not given us any information. If anybody is going to use these specifications they have to look it up.

In Article 5 (d) they refer to the "Standard Method of Test for Quantity of Soft Pebbles in Gravel," a method of test adopted by the American Association of State Highway Officials. They are asking us to adopt all of those things which they have not presented to us. I am not criticizing those matters because they may be all right, but our specifications should be sufficient for the man who is going to use our Manual without having to look up three or four other books, in addition to our own.

Therefore, I move that this specification be referred back to the Committee with instructions to bring in or to state these matters taken from other organizations, giving proper credit for them, but showing in complete form in our Manual everything that is to be adopted.

The President:—The motion before the convention is on the adoption of the Committee report. I understand Mr. Baldridge desires to amend the motion, that this be referred back to the Committee. Do I correctly understand it, Mr. Baldridge?

Mr. C. W. Baldridge:—Either an amendment or a supplemental motion. An amendment is satisfactory.

Chairman A. D. Kennedy:—As a matter of information, the instructions to reporting chairmen were that it is permissible to refer only to specifications published by other organizations, accepted organizations, and in the interests of economy and simplicity the printing of the whole specification is not desirable in these Bulletins. Anyone who is interested in the matter can refer to these specific specifications and get the information that is desired.

Mr. C. W. Baldridge:—I should like to ask what economy there would be in saving a few cents on printing the full set of specifications in our Manual over having to buy two or three other books in order to get them. And, furthermore, it is not necessary to quote the ASTM specification unless we wish to. We can write our own specifications, which will agree with theirs, if we want to handle it in that manner. We should certainly make our Manual complete, which we are not doing when we make it necessary for whoever wants to use it to look up two or three other sources of information.

Chairman A. D. Kennedy:—In reply to that, I appeal to the Chairman for a decision in the matter. We can give the specifications, but that is contrary to our instruction, and it is not within the province of the Committee Chairman for action.

Mr. C. W. Baldridge:—I will again call attention to the fact that if they have such instructions, those instructions are contrary to the rules of this Association, as given in Rule 4, governing matter for inclusion in the Manual. That rule has not been revised so far as I have heard.

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western):—That is a question of policy rather than on this particular subject. We had it up in the Masonry Committee, where we refer to any number of specifications of the ASTM and other societies. We have taken this up with Mr. Brumley, as Chairman of the Special Committee on Manual. We decided that inasmuch as we have representation on most of these committees of the ASTM which are charged with drawing up specifications on aggregates, cement, and other material, it would be satisfactory to make reference at the present time to these specifications and in due time possibly publish a volume giving the specifications on all materials and have that set up in a separate pamphlet form. I think it is a matter for the Board of Direction to decide once and for all as to the policy of this Association in the matter of specifications of the ASTM and other allied bodies.

Mr. J. C. Irwin (Boston & Albany):—In regard to this, Mr. Baldridge usually gives us some very good ideas, but it is perfectly impossible for us in our Manual to duplicate the work that is done by standardizing bodies in allied subjects. We can best refer to these standards which our men have taken part in creating and also which are not confined specifically to the subjects which we are trying to prepare in shape for our members but which would run into an interminable number of allied subjects.

My point is that in the subjects which are allied to the one under discussion, there are many interests involved which are taking part in standardization matters and in which it would not only duplicate but complicate the situation if we should undertake to follow out the detailed specifications for allied subjects. Incidentally, the idea of referring to ASTM specifications in this way is that as they become standard under the procedure of the American Standards Association, we shall then refer to them as standards of the American Standards Association, the ASA, of which the Association of American Railroads is a Member Body. I think that is very much worth while in this stage of development of our subjects.

The President:—I should like to ask Mr. Brumley if he will enlighten the convention on this moot question.

Past-President D. J. Brumley:—This question has arisen on several occasions during the past year in connection with revision of the Manual. In discussing the matter with Mr. Hirschthal and also with several other Committee Chairmen, it seemed to me that to include the specifications of the ASTM in various places in the AREA Manual would add a great deal to the volume but would not accomplish very much. In this particular case, if these ASTM specifications are repeated in the AREA Manual we will have four or five pages of material more in our Manual created by another organization for which the AREA Manual is not responsible. Other organizations are recognized as organizations capable of writing standards for specifications for material such as is now listed in the AREA Manual. I am inclined to think, in the interest of economy, that the ASTM specifications should not be repeated in the AREA Manual.

The President:—The question is on the amendment to refer the report back to the Committee for further study, the original motion being that the Committee report be adopted. I will first put the question on the amendment to refer back to the Committee. All those in favor of the amendment will signify by saying "aye"; contrary-minded, "no". The "noes" have it and the amendment is not accepted. The question is now on the original motion to accept the Committee report for printing in the Manual.

(The motion was put to vote and carried.)

Mr. Stanton Walker:—The 1929 Manual of the Association includes a specification for pit-run gravel ballast, which was adopted in 1921. The Committee also presents revisions for that specification which, for the most part, involve only changes in form. The existing specification outlines requirements for three classes of railways—A, B, and C. The proposed revision does not refer to classifications of railways, but provides for two grades of pit-run gravel ballast having approximately the same requirements as now stated. More specific and up-to-date information as to methods of testing the pit-run gravel ballast have also been included.

Chairman A. D. Kennedy:—I move the adoption of the new specifications for pit-run gravel ballast as given in this Bulletin, 384, on page 563.

The President:—It is moved and seconded that the report as made by the Committee be adopted for printing in the Manual.

(The question was put to vote and carried.)

Mr. M. I. Dunn, Jr.:—On page 564 and at the top of page 565 of the Bulletin we show certain additional recommended revisions of the Manual. I will just read them by headings.

"Specifications for Burnt Clay Ballast," which we propose to withdraw.

"Cinder Ballast." The material on this subject is to be revised slightly, cutting out some self-evident matter in the interest of brevity.

"Proper Depth of Ballast." We propose to withdraw everything under this heading.

"Ballast Sections," similarly to be withdrawn.

"Organization and Distribution of a Ballast Raising Force of 77 men." This matter is obsolete. We propose to withdraw it from the Ballast section and refer it back to the Committee on Outline of Work.

Similarly, with the "Organization and Distribution of a small Emergency Ballast Gang."

We also propose to withdraw the matter on "Use and Limitation of Mechanical Tools," the "Use of Mechanical Tampers," and the "Rules for Care of Mechanical Tamping Machines." This does not properly come under the province of this section.

"Cleaning Foul Ballast." Some revisions to bring this matter more nearly up to date.

"Reinforcement under Ballast" is to be withdrawn, the subject to be referred back to the proper committee.

"Stone and Gravel Ballast Required per Mile of Track." We propose to withdraw that matter, inasmuch as we propose to withdraw the standard section now shown in the Manual.

"Shrinkage Allowance," similarly, is to be revised, and we are recommending the matter shown at the top of page 565.

We also propose to withdraw the matter on "Ballasting by Contract."

We move that these revisions be adopted.

The President:—It has been duly moved and seconded that these revisions as recommended by the Committee be adopted.

(The motion was put to vote and carried.)

Chairman A. D. Kennedy:—The next matter is "Specification for Stone Ballast." We are not offering this for adoption at this time. However, we are offering it as information and we give you warning that we are going to ask for its adoption next year. We invite discussion on these proposed specifications at this time in order that we may get the thoughts of this Association.

Mr. Goldbeck, largely instrumental in preparing this new specification, will present it.

Mr. A. T. Goldbeck (National Crushed Stone Association):—Your Committee has carefully considered the specifications for stone ballast as adopted for inclusion in the Manual in 1931, together with subsequent revisions. It now offers for criticism and suggestion a proposed revised specification which it hopes to present for adoption in 1937, in modified form if desired.

The present specification differs from the 1931 specification in form and in certain details. The new form is written in accordance with the present-day tendency in specifications for materials, that of writing size and quality requirements first in short, concise form, followed later by references to recognized standard methods of testing. It is felt that this form permits of the incorporation of these specifications by any railroad into its own standards with very little change.

As explained by Mr. Walker in connection with the gravel specifications, the sizes of stone ballast are now expressed in terms of square opening laboratory sieves, for the same reasons stated by him. The sizes given are in conformity with the proposed standard sizes of the Division of Simplified Practice of the United States Department of Commerce. A range of sizes is given from which a selection or selections may be made by the individual railroad for its own particular needs.

In line with present practice, deleterious substances are limited in a definite manner instead of in the more general terms of the old specification.

The quality of the rock in the absence of proved service record is still described in terms of toughness, percentage of wear, soundness and absorption, but the cementing value test has been omitted as the result of a comprehensive investigation which is included under Appendix A-2 of the report.

Appendix A-2, Comparative Cementing Value Tests. The details of this investigation are given in full and only the essential features need be mentioned at this time.

In a note accompanying the 1931 specifications for stone ballast, the cementing value for desirable limestone was given as four lb. and for trap rock as one lb. per square inch. Tests by the speaker showed cementing values for limestones of recognized quality to be well over 500 and extending up to above 1000 lb. per square inch. An excellent trap rock had a cementing value of 590 and even crushed quartz, one of our least cementitious materials, gave a value of 32 lb. per square inch. So, obviously, the published values of one and four lb. were much in error and could not have been based on tests. Thus the whole subject of the cementing value test became an active one for investigation.

The Chairman of the Sub-Committee on Stone Ballast, Mr. Podmore, decided to discover how extensively the AREA cementing value test was being used by the railroads and a questionnaire showed that only 6 of the 58 railroads replying have a cementing value requirement in their specifications varying all the way from 1 lb. to 450 lb. per square inch. Certainly such a wide range in requirements indicates the existence of an error somewhere. As already stated, even crushed quartz shows a value of 32 lb. per square inch.

Accordingly, it was determined to discover the real significance of the test as now described. As a first step, the uniformity with which the test could be duplicated in a single laboratory and in different laboratories was proposed for investigation, for obviously if closely similar results cannot be obtained from day to day in the same laboratory or in different laboratories, there is something wrong with the test method. With such a method it becomes impracticable to set specification limits which will discriminate material of high from material of low cementing value.

A cooperative series of tests was run in the three laboratories which volunteered to engage in this work. Three samples of rock—trap, dolomite and limestone—were divided and sent to each of the laboratories, and each laboratory performed the cementing test five times on each sample. The detailed results are given in the report. Briefly, the concordance of results, even in the same laboratory on the same sample of rock, was very disappointing, and there was no agreement as between different laboratories. For illustration, on one of the samples of rock one laboratory obtained 484 pounds as against only 132 pounds in another laboratory. One result was over 3½ times as much as the other.

Certainly such a test can have no particular value for specification purposes and accordingly the cementing value test has been omitted from the proposed specification.

Appendix A-3, Report of Specification Test Limits. The specification for stone ballast covers a naturally occurring material having different physical characteristics in different sections of the country. Considerations of economy must lead to the use of those materials of proved worth which are locally available. Thus it seems impracticable to set up, in a national specification, hard and fast quality requirements for stone ballast. It does seem to the Committee, however, that it would perform a service by indicating those test limits which will differentiate the different qualities of rock for ballast purposes. Only by comparing service results with physical tests can really significant specification limits be made. This comparison of service value with physical tests perhaps can best be done by each railroad, but for general guidance a table of comparisons has been included based on work done by the Ballast Committee many years ago. This table must be exceedingly approximate and it must naturally be influenced by the personal equations of the numerous individuals who reported service behavior. The table is distinctly not offered as anything but approximate and the reason for publishing it is that no other comparisons of laboratory results with service behavior have been found. Such a table should serve a useful purpose if liberally interpreted and it therefore has been included in our report as a rough interpretation of laboratory tests in terms of service behavior.

Mr. C. W. Baldridge:—Is no opportunity going to be given for discussion on the subject or no action to be taken on it?

The President:—This report is submitted by the Committee as information only and no action is necessary by the convention.

Mr. C. W. Baldridge:—It certainly should be open for discussion, however.

The President:—The Chair will be glad to hear discussion on that admirable presentation.

Mr. C. W. Baldridge:—I have a remark I want to make about the proposed specifications for cementing value test which they propose to remove. At the top of page 569 they quote the present specifications for determining cementing value in which they propose to take a briquette .95 in. in diameter and .95 in. deep and subject it to 1877 pounds pressure in order to find the cementing value. That is not a cementing value; that is a briquetting vâlue.

On the subject of cementing value, if this Committee cannot determine how to make a test for cementing value, I recommend that they read the specifications for cement tests given in the Masonry Committee's portion of the Manual, page 661, 1929 Manual.

The need for cementing value in determining the value of ballast material is plain. It is a simple fact that where any kind of stone that has a high cementing value is used as a ballast, after it has become pulverized as happens under the tamping picks, hammers, and so forth, it reaches a condition of weak cement and retards drainage through the ballast. And the very fact that all ballast is subjected to more or less pulverising under the hammers makes it very important, I believe, to obtain or to include a specification for cementing value.

I am not objecting at all to removing from the Manual the figures they now have. I think it is an absurdity to propose when making a test block, putting less than a cubic inch of any material under 1877 pounds pressure to determine its value as a cement.

The President:—The Committee, I am sure, will be glad to receive additional comments or suggestions from the convention as an aid to them in their further studies of this assignment. I think, Mr. Baldridge, you have made some helpful criticisms.

Mr. Meyer Hirschthal:—I have one editorial suggestion on paragraph 15 on page 567, where the first sentence refers to the producer and the second to the manufacturer, as if the two were different individuals. I suggest the rewording of that second sentence that would permit the producer to have the defective ballast returned at his own expense if he so desires. It is just a suggestion.

The President:—As there are no other suggestions, the report will be received as information.

Chairman A. D. Kennedy:—I will now call upon Mr. Wicker, Chairman of the Sub-Committee, to render the report upon "Specification for Prepared Blast Furnace Slag Ballast."

Mr. C. S. Wicker (Buffalo Slag Company):—The Specification for Prepared Blast Furnace Slag Ballast appears in Bulletin 384, page 575. The specification is divided into three parts. In accordance with the Secretary's suggestion to Committees submitting specifications, I shall read only the various headings.

First is "General". Under the heading "General" reference is made to "Blast Furnace Slag" which was defined earlier in this meeting. A new definition appears in Bulletin 384, page 560, paragraph 9.

Under Part II, "Size," the sizes proposed in this specification are in accordance with standard sizes proposed by the Joint Technical Committee of the Mineral Aggregate Associations.

"Weight—Soundness—Frequency—Selection of Samples—Place of Tests."

The President:—I suggest to the Chairman that he proceed with the Committee report, pausing after each recommendation so as to afford opportunity for questions from the floor and then proceed if there are none. If there are questions will the speaker rise and state his question or objection.

Mr. C. S. Wicker:—Part III, "Production Requirements."

First is "Handling", then "Cleaning—Unit of Quantity—Weighing—Defect Found After Delivery—Inspection."

Your Committee moves the adoption of these specifications for inclusion in the Manual.

The President:—It has been moved and seconded that the report of the Committee be accepted and adopted for printing in the Manual. Are you ready for the question?

Mr. Meyer Hirschthal:—I have just one question to ask. Again it is on the same point on which I arose previously on the ballast. The question is whether the maker of slag is a producer or a manufacturer. I think we ought to get together on that term. It is used both ways throughout these specifications. I think the term "producer" would be perhaps more suitable than "manufacturer."

Mr. C. S. Wicker:—Mr. Hirschthal is correct. Blast Furnace Slag is a mighty important by-product, but being a manufactured product, it was thought by the Committee that the term "manufacturer" should be used rather than "producer".

Mr. Meyer Hirschthal:—I think slag is a by-product rather than a manufactured product.

Mr. C. S. Wicker:—Yes, it may be a by-product. However, it is manufactured. I am sure the Committee will give this question consideration.

Mr. Meyer Hirschthal:—That is immaterial so long as you use it in the specification in the same way.

The President:—Is there any further comment? If there is nothing further, the question is now on the adoption of the Committee report.

(The question was put to vote and carried.)

Chairman A. D. Kennedy:—That completes the report of the Committee.

The President:—Mr. Kennedy, I desire to congratulate you on the report of your Committee. I have been especially interested, as a former trackman, in your assignment and the way you have handled the subject. The Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON TIES

(For Report, see pp. 417–420.)

Mr. John Foley (Pennsylvania):—In Bulletin 383, on page 417, is the report of the Committee on Ties. It is brief and non-controversial.

On Subjects 5, 6, 7 and 8, there are no statements to make other than to report progress.

No report is made on Subject 3 because it was decided not to bother the railroads with any more questionnaires than were being inflicted on them.

On Subject 4, the statistics for 1934 have been in your hands for several months. As usual, they are entitled to study if you are interested in the economics of using crossties of the right woods and sizes.

On Subject 2 there is presented as information a statement which will be briefed by the Chairman of the Sub-Committee, Mr. Clarke.

Mr. H. R. Clarke (Chicago, Burlington & Quincy):—The Committee during the past year inspected a very large number of ties and the result of this inspection is contained in the report on page 418 of Bulletin 383. A number of roads still do not buy according to AREA specifications and observation on three of these roads during the past year confirms previous observation that no superiority was found in their ties to justify variation from AREA standards. The Committee would also call attention to the quotation from the report by the Section of Purchases, Federal Coordinator of Railroads, as found on page 418, as indicating the need of adherence to a uniform standard and that in AREA specifications we have such a standard. The report is submitted as information.

The President:—It will be so accepted.

Chairman John Foley:—Last year there was submitted a specification on the adzing and boring of ties for the information of the Association. During the year, due to the fact that the Committee on Track could not agree on a single standard tie plate, one change was made in that specification by eliminating the requirement as to a specific width of adzing. Since the machining of cross-ties covers more than the adzing and boring of them and the practice has become quite general, the Committee enlarged their province to cover the other phases of machining, and the report will be presented for adoption as recommended practice by Mr. Chapman in the absence of Mr. Belcher, Chairman of the Sub-Committee.

Mr. E. E. Chapman (Santa Fe):—The specification as submitted here is to cover the complete machining of the ties, giving the recommended tolerances on the adzing, grooving, boring, incising and trimming of ties, and specifying the proper methods of branding. This specification has been gone over carefully this year, as stated by the Chairman, and it is felt that it should be accepted and placed in the Manual as recommended practice, and I so move.

The President:—It is moved and seconded that the material as presented by the Committee be accepted for publication in the Manual.

Mr. G. H. Tinker (New York, Chicago & St. Louis):—I think the term "machining" is not proper. The term "framing" should be used instead of "machining."

Chairman John Foley:—The Committee uses "machining" because they believe that it covers all the various operations. The Committee will welcome any suggestions as to a better word, but believes that "machining" is more satisfactory than "framing," which is a term not thought of in connection with incising or branding.

Mr. G. H. Tinker:—I wish to say in that respect that the term "machining" applies technically to work done upon metal objects. It is not properly applied here. When applied to timber the proper term is "framing." That is in general use and is readily understood. I think the term "machining" is an innovation and many people may ask what is meant by it.

Chairman John Foley:—We believe, since the ties are put through a machine, that they are machined, and consequently that "machining" is satisfactory. The Committee gave consideration to various words and finally resolved that "machining" was the one that best expressed what they had in mind.

(The question was put to vote and carried.)

Chairman John Foley:—On page 417 you will find a couple of minor items in connection with Subject 1, Revision of Manual. When the report on the care of ties after distribution was adopted, there existed in connection with the ironing of ties only one common device, which was in the form of an "S." Since then other forms have come into general use, and in order not to restrict the requirement to "S's," we recommend the elimination of the letter "S" in that paragraph.

In the same portion of the Manual we recommend the elimination of a phrase which has no longer any application. That is, instead of saying "and to see that no tie is held in storage longer than one-fifth of its estimated life in track," we leave it to the judgment of those in control of ties how long they should be held in storage.

I move the revision of the Manual in these two instances.

The President:—It is moved and seconded that the revision as reported by the Committee be accepted for printing in the Manual.

(The question was put to vote and carried.)

Chairman John Foley:—That completes the report.

The President:—Mr. Foley, I desire to thank you for the good work which your Committee has done during the year, as evidenced by their report just made. The Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON RAIL

(For Report, see pp. 421–462.)

Mr. Earl Stimson (Baltimore & Ohio):—The Rail Committee this year offers quite an extensive revision of the Manual for approval. A progress report on research work that is being conducted at the University of Illinois on the joint account of this Association and our friends of the Rail Manufacturers' Technical Committee will be presented by Professor Moore, in charge of the investigation, at the end of the presentation of this report.

The usual compilation of rail statistics will be offered as information by Mr. Barnes, Engineer of Tests of the Rail Committee.

A report on the Cause and Prevention of Rail Battering will be presented by Mr. Graham with recommendations for approval.

On the subject of Economic Values of Different Sizes of Rail, there will be no report presented.

A progress report is presented on the subject of Rail Lengths in excess of 39 feet.

A progress report on the Cause of the Corrugation of Rails.

No report on the subject of Service Tests of Various Types of Rail Joints.

No report and recommendations to drop the subject of the Effect of Different Kinds of Ballast on Life of Rail and Upon Rail Failures.

There will be a report and recommendation for Design of Rail Joints for the 90-lb. RA-A and the 100-lb. RE rail sections. These will be submitted for approval.

Taking up the first subject, namely, that of Revision of Manual, quite an extensive revision and rearrangement of definitions is presented for approval. I move that they be approved as submitted.

The President:—It is moved and seconded that the definitions as presented by the Committee be accepted for printing in the Manual.

(The question was put to vote and carried.)

Chairman Earl Stimson:—Certain revisions in rail record forms are presented, and they will be explained by Mr. Barnes, Engineer of Tests of the Committee. These will be found beginning at the bottom of page 427.

Mr. W. C. Barnes (Rail Committee):—The rail record forms appear in the Manual, page 174. They are listed and a description of each form is given and the form itself presented.

In preparation for the republication of the Manual these forms have been carefully studied to see if there were not some that were more or less obsolete, and the Committee recommends that Form 401-A, Report of Chemical and Physical Examination of Rails; Form 401-B, Certificate of Inspection; Form 401-C, Report of Shipment; 402-A, Report of Rail Failure in Main Track; 402-C, Yearly Summary of Rail Failures; 402-E, Statement of Transverse Fissure Rail Failures; 402-D, Statement of Rails in Main Tracks, and 403-B, Diagram of Lines of Wear, should be retained as satisfactory and the three remaining forms be eliminated. No action required on the retaining of those forms as they are already in the Manual. The recommendation does cover the elimination of Form 402-B, Monthly Summary of Rail Failures, page 182 of the Manual, 403-A, Diagram of Location of Rails (which is used in special test work), and 403-C, Record of Wear. It has been found that these forms are seldom if ever used. We think they should be eliminated.

The arrangement is changed somewhat. Instead of a separate list of these various forms, the description of each form will now appear on the page containing the form.

The recommendation also includes a revision of Form 402-A, Report of Rail Failure in Main Track, commonly called the Foreman's Report. That recommendation appears on page 430 of the Bulletin. The revision of that form referred to in last year's report has been completed. Many questions no longer considered necessary, and others usually answered in a routine manner, have been omitted. The form has been otherwise simplified and the illustrations and diagrams of rail defects improved so that it is much easier for the foreman to fill out. It is expected that arrangements will be made whereby the Association will be able to furnish either the printed form or electrotypes of this form to individual railroads desiring to use it. Your Committee recommends adoption of the revised form for printing in the Manual.

I move the elimination of the three forms mentioned and the revision of Form 402-A.

The President:—It is moved and seconded that the recommendations of the Committee with respect to these forms be accepted and adopted for printing in the Manual.

(The question was put to vote and carried.)

Chairman Earl Stimson:—The balance of the matter under Revision of Manual, beginning with rail specifications at the bottom of page 425, will be presented by Mr. Bronson, who is a member of the Sub-Committee handling the revision of the Manual. Mr. Blaess, the Chairman of the Sub-Committee, who did wonderful work on these revisions, unfortunately is unable to be with us today.

Mr. C. B. Bronson (New York Central):—The first revision called for is on page 425 and pertains to some slight changes and modifications in rail specifications. It is carried over on pages 426 and 427. These items are merely clarifying some of the points in connection with specifications and I should like to move that the changes be made and adopted for recommended practice in the Manual.

(The motion was put to vote and carried.)

Mr. C. B. Bronson:—The next point, on page 427, pertains to Inspection Force, which is merely a revision and clarification, and I make a similar motion for that section.

The President:—It is moved and seconded that the recommendations of the Committee be accepted for printing in the Manual.

(The question was put to vote and carried.)

Mr. C. B. Bronson:—On page 428 are the Specifications for Open-Hearth Steel Girder Rails, and also the girder rail sections, which are tied in closely together, carried over on page 429.

This harmonizes with the American Transit Association to bring up to date these specifications, and a similar motion is recommended for that portion of the report.

The President:—It is moved and seconded that the report as submitted by the Chairman of the Committee be accepted and adopted for printing in the Manual.

(The question was put to vote and carried.)

Mrs. C. B. Bronson:—On page 429 in the middle of the page appear the "Tables of Bolt Dimensions." This merely rearranges the matter of the length of the bolt, also a slight change in the thickness of the nut, and the recessing of the nut. While this is somewhat at variance with the American Standards Association, it is covered fully by a special paragraph right below the table as shown.

We recommend a similar motion on this portion of the report.

The President:—It is moved and seconded that the report as submitted be accepted and adopted for printing in the Manual.

(The question was put to vote and carried.)

Past-President D. J. Brumley:—There is a minor matter on page 429 that I want to call attention to. Near the middle of the page is a paragraph reading: "Between Paragraphs (10) and (11) insert a new paragraph (13)—"Joint Bars of the Sections shown as 128-lb. RE 7-A."

I note there is a provision that the bars will be 26 inches long but the spacing of bolts would appear to make this only 22 inches long. It occurs to me that one bolt spacing dimension has been omitted. The spacing dimensions should be 2½ inches—4 inches—4 inches—5 inches—4 inches—4 inches—2½ inches.

Mr. C. B. Bronson:—I believe you are correct, Mr. Brumley, on that point. I believe that is a typographical error.

The President:—Unless there is objection, I shall understand that the changes as recommended by the Committee will be made without further action by the convention.

Mr. C. B. Bronson:—On page 430, near the middle of the page, are the "Specifications for Quenched Carbon Steel and Alloy Steel Track Bolts." For a number of years there has been a difference in the specifications with those of the ASTM.

The Chairman has called attention to one item that I skipped over, at the bottom of page 429, "Elimination of the following material from the Manual is recommended for the reasons stated."

"Plan of Drop Test Machine." On account of the fact that all of the rail mills are equipped with this machine and the drawings, working plans, and detailed dimensions when given are indistinct and hard to read, we figured it would be just as well to leave that out of the Manual, and I would so move.

(The motion was put to vote and carried.)

Mr. C. B. Bronson:—I will offer an apology due to the fact that I am pinch-hitting for Mr. Blaess. He split this job into three portions and some of these items in here were marked out for me and some for Mr. Barnes and some for Mr. Stimson.

On page 430 I overlooked one other item. That is the matter of "Rail Batter." This material is not in accord with the present-day knowledge of the subject and its elimination from the Manual is recommended. I so move.

The President:—It is moved and seconded that the material as read by the Chairman of the Committee be deleted from the Manual.

(The question was put to vote and carried.)

Mr. C. B. Bronson:—Taking up the track bolt specifications, as I mentioned previously, the ASTM and the AREA specifications have been at variance for a considerable period of time; in fact, they have never been together on general clauses and details, so an effort was made this year to harmonize and bring up to date this very important specification. We had some interesting meetings with the Manufacturers' Association, the ASTM, and we believe we have worked out a specification which is more complete than has ever been presented to the Association before and at the same time that fully embodies the necessary requirements and it has actually been accepted by the ASTM as a tentative standard.

In view of this fact and in view of the completeness of the specification, we should like to offer this for adoption by the Association and inclusion in the Manual. I so move.

The President:—It is moved and seconded that the specification as presented and recommended by the Committee, be accepted for printing in the Manual.

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western):—Is it the first appearance of the specification in our Bulletin?

Mr. C. B. Bronson:—Yes.

Mr. Meyer Hirschthal:—Is it quite in order to present it the same year for inclusion in the Manual rather than have it as information to study? The tentative standard is really not an adopted standard of the ASTM. As I remember it, tentative accepted standards are for the purpose of discussion before being printed as final standards. I think we should continue that policy and permit this to appear as information for a year before adopting it as a final recommended practice for printing in the Manual.

The President:—I will say for the information of the speaker that there is ample precedent for the action of this Committee.

Mr. Maro Johnson (Illinois Central):—My only comment is that this particular specification was printed in the Proceedings last year and there has been only minor change since that time.

The President:—Is there any further question? If not, the question is on the motion for adoption.

(The motion was put to vote and carried.)

Mr. C. B. Bronson:—The next specifications are on page 433, at the bottom of the page, "Specifications for High Carbon Steel Joint Bars." Here again we had a conference with the ASTM on this specification as well as on the specifications for quenched carbon steel joint bars with an effort to harmonize the two, and not only that but to bring them up to date because both of them were obsolete, and they have been in need of revision to modernize them in connection with present-day practice.

The ASTM has not taken definite action on this yet except through their Sub-Committee, which has formally voted on the two specifications, this one and the quenched carbon steel bar specification. They call for one little revision over which we had considerable discussion, which is under the item of "Workmanship." Our specification as drawn up indicates a camber in a vertical plane of 1/32 inch in both the 24-inch and 36-inch bar. The ASTM considered 1/16 inch as essential for the 36-inch bar and carried the specification through on that point. We had our meeting yesterday and by vote decided to change that one item so that the revision will be for 1/16 inch in the 36-inch, with the 1/32 inch in the 24-inch length remaining as shown at present.

With this change, I should like to recommend that the specification be adopted for the inclusion in the Manual, and I so move.

The President:—It is moved and seconded that the specification (with the alteration stated) as presented and recommended by the Committee, be adopted for printing in the Manual.

Mr. C. W. Baldridge (Atchison, Topeka & Santa Fe):—In view of the attitude toward economy on printing, I am wondering why it is necessary to have specifications for high carbon steel joint bars and specifications for quenched carbon steel joint bars in which the only material difference that I can see is that the high carbon steel joint bar requires a carbon content not under .45 and a tensile strength of 85,000-lb., while the specification for quenched carbon steel joint bars permits a carbon minimum of .35 and requires that the tensile strength be 100,000-lb. It seems to me that the two specifications could be combined with very little difficulty.

Mr. C. B. Bronson:—If you will read them carefully, Mr. Baldridge, you will find there are a number of essential differences between the two, as to the method of testing, the physical and chemical properties, and some other items, such as marking and stamping, and so on. That warranted two separate specifications. In addition to that, the ASTM carries through a series of four specifications. We have boiled this thing down to two and they are willing to go along with us, and we considered, in light of the fact that you have these variations between the two specifications, it was necessary to work it out that way.

The President:—Is there any further question? If not, the question is on the adoption of the Committee recommendation.

(The motion was put to vote and carried.)

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Mr. C. B. Bronson:—On page 436, "Specifications for Quenched Carbon Steel Joint Bars," we have the same comment to make as we did in connection with the previous specification, and I move adoption of this specification for inclusion in the Manual.

(The question was put to vote and carried.)

Chairman Earl Stimson:—The report on Rail Failure Statistics, which can be found on page 439, Appendix C, will be presented by Mr. Barnes.

Mr. W. C. Barnes:—Rail Failure Statistics for 1934 present data which are comparable in every respect with those presented last year, and as they are fully explained in the text and there is no item that seems to require special elaboration, I move that the Rail Failure Statistics for 1934 be received as information.

The President:—It will be so received.

Mr. W. C. Barnes:—Transverse Fissure Statistics for 1934. These are also presented in the usual manner. This is a cumulative report. It now includes a total of 63,227 service failures, a detected total of 16,078, making a grand total of 79,305 transverse fissure failures.

The fissure failures have undoubtedly increased during the past year. Notwithstanding an increase in detected failures, the service failures have increased.

I move that these statistics be received as information.

The President:—It will be so received.

Mr. W. C. Barnes:—A very short report on the AAR Detector Car appears on page 454, which does not require any elaboration. It is offered as information. I move that it be so received.

The President:—It will be so received.

Mr. W. C. Barnes:—On page 460 there is a report of the Sub-Committee on Cause of the Corrugation of Rails. The Committee has given this matter considerable study, reviewed the extensive work that has been done by the American Transit Association, has made some observations in track, and has concluded that the problem of corrugation on steam roads is not a really serious problem. In any cases where it may be serious, there are means provided for removing the corrugations by grinding. And as to determining a general cause, it seems to be quite out of the question without the expenditure of a large amount of funds, which would not seem to be warranted.

The Committee therefore recommends that this report be received as information and the subject be discontinued.

The President:—It will be so received.

Chairman Earl Stimson:—The subject, "Cause and Prevention of Rail Batter," will be reported by Mr. Graham, the Chairman of the Sub-Committee.

Mr. F. M. Graham (Pennsylvania):—The Committee has made a detailed study of the prevention of rail batter by various methods including heat treatment of rail ends.

Some of the results of previous studies are included in progress reports found in AREA Proceedings, page 371, Vol. 32 (1931), and page 854, Vol. 35 (1934).

Results have been observed on a large mileage distributed over various railroads where several methods of heat treatment have been used, dating back as far as 1927.

The following vertical longitudinal graph, Fig. 1, is a typical illustration of the result which can be obtained by heat treatment.

The profile of the top of the rail was obtained after the joint was subjected to 201 million gross tons of traffic over a four and one-half year period. The rail was 130-lb. section with six-hole heavy joint bars.

Fig. 2 shows an adjacent untreated joint in the same track, subjected to the same traffic.

The graphs shown in Fig. 1 and 2 were obtained using the following profile instrument. This instrument plots to actual scale longitudinally and to fifty times actual scale vertically.

The actual distance between the vertical lines appearing at the sides of the graphs is 24 in.

It is not thought that the high spots at rail ends appearing in graph shown in Fig. 1 would become objectionable within the life of the rail, but, if so, they could be ground down at a nominal expense.

No other successful method of preventing rail batter has been developed, and as a result of these studies, the Committee has reached the following conclusions which it recommends for publication in the Manual under heading "Batter":

"1. Objectionable batter can be prevented by the hardening of rail ends through suitable heat treatment with a Brinell hardness not exceeding 400."

I should like to stop here just a moment and say that since this number was determined by the Committee at a meeting in New York, an examination of successful hardening under large tonnage indicates that even 500 Brinell has not had any damaging effect, and therefore with consent of the Committee, and during the progress of our study I should like permission to revise the 400 to 450 and I believe we would be safe in doing so.

"2. When rails are laid, the difference in surface heights of adjacent rail ends should be corrected by grinding. After heat treatment of ends and before traffic, the hardened ends should be cross-ground or slotted.

"3. For the purpose of securing uniform measurements of rail batter in further studies, a rail batter gage similar to that illustrated in Fig. 4 and 5 should be used.

"4. This gage should be placed in the center of the width of the rail head spanning the joint. On one-way traffic the center of length of gage should be placed on the receiving rail 2-in. from the center of the joint opening. On two-way traffic, the gage should be placed with its center of length over the center of the joint opening.

"5. Readings can be taken either with the dial depth gage or the taper gage as shown. The dial depth gage is to be set at zero with the master gage as shown. When a taper gage is used, it should be graduated with zero point located where the gage is 0.1-in. thick. Both should be graduated and read to 0.001-in. per graduation. Readings should be taken at extreme end of running contact on rail, one-half inch from center of joint, one inch from center of joint, and subsequent inches to the end of graduations on the gage. Joint openings in sixteenths of inches should be noted at outside of rail at gage height and also minimum opening between wheel contact points at top of rail.

"6. Readings should be entered on blank form similar to that shown in Fig. 6.

"7. Readings for a stretch of track shall be averaged for each designated graduation on the gage furnishing an average profile. Gross tonnage figures should be furnished for period covered between readings.

"8. The area in square inches between average profiles secured from measurements should be equated to the basis of ten million gross tons of traffic and the resulting area multiplied by 1000 representing a value termed 'Batter index.'"

The above report is submitted as partially complete. The Committee will continue to study other phases of the subject, including results to be obtained from the various methods of heat treatment now available.

I should like to add in explanation that we have explained somewhat in detail the method of collecting information in the future. Attempts to do so in the past have resulted in wide diversity of bases of reporting and we should like, for the benefit of the Committee, to utilize the methods here outlined.

I therefore move for inclusion in the Manual all of the matter on page 456, including the tracings, and with the exception of the bottom paragraph on that page.

The President:—It is moved and seconded that the report of the Committee be adopted for printing in the Manual.

Past-President D. J. Brumley:—I should like to ask if the recommendation includes the tables on pages 458 and 459.

Mr. F. M. Graham:—The forms illustrated should be printed and available for use in a proper study of the subject.

Past-President D. J. Brumley:—They should be included in the Manual?

Mr. F. M. Graham:—Yes.

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western):—Does it include the revision of that figure 400 to 450 Brinell hardness?

Mr. F. M. Graham:—It is my thought, together with that of others with whom I had an opportunity to speak about it since hearing about it, that we should make that 450 and not include the 400.

Mr. Meyer Hirschthal:—One more question: Am I correct in interpreting Fig. 1 and 2 as being the result of individual tests upon untreated and treated rail? Is it just one test or an average?

Mr. F. M. Graham:—They are typical of a large number of joints.

Mr. Meyer Hirschthal:—It is a profile of one individual case?

Mr. F. M. Graham:—One individual joint of which many are available.

(The question was put to vote and carried.)

Chairman Earl Stimson:—The Association has already adopted a joint bar and assembly for both the 131 and the 112-lb. rail. This year we are offering a joint bar and assembly for the 90-lb. RA-A and the 100-lb. RE rail.

The report will be found on page 462 of the Bulletin and will be presented by Mr. Willoughby, Chairman of the Sub-Committee.

Mr. J. E. Willoughby (Atlantic Coast Line):—The subject assigned was "Design Joint Bars for 90-lb. RA-A and 100-lb. RE rail sections."

In its study your Committee has given consideration to various types of bars and has used the data accumulated by the Committee on Stresses in Railroad Track. The design now submitted is the unsymmetrical type. That type is the advantageous type for rail with fishing space as small as that of the rail sections for which these bars are designed and most nearly conform to the requirements as to work to be done by the joint bar.

Investigations of the properties of joint bars available for use with these 90-lb. and 100-lb. rail sections developed that the templets of those available do not best conform to the needs of the joint, and in proceeding with its study your Committee made no attempt to avoid the use of curved lines, angles and other features of proven merit which appear in joint bars of current use. Nevertheless, the design as now submitted does not infringe on any existing patents. The General Counsel of the Eastern Railroad Association states: "My conclusion is that Study III and Study IV, Joint Bars, submitted . . . can be made or purchased and used without danger of infringement of any existing patent."

The Executive Committee of the Eastern Railroad Association adopted this report of its General Counsel. The General Counsel for the Western Railroad Association states: "Basing my opinion on Mr. Wolhaupter's advice that the Rail Joint Company has no patent which it considers infringed, I believe you can safely use these bars."

The Sub-Committee in charge consulted Dr. A. N. Talbot during the progress of this work and received suggestions of value from him. Dr. Talbot's judgment of the finished design now presented is: "The flanged section (angle-bar type) proposed by the Sub-Committee for the 90 and 100-lb. rails is a marked improvement over the older angle bars for these rail sections, as is apparent by a comparison of the new section proposed in the Sub-Committee report and those shown for the angle bars made by the Rail Joint Company in the past." The design is shown opposite page 462.

I recommend the adoption of these designs for publication in the Manual.

The President:—It is moved and seconded that the designs recommended by the Committee be adopted for printing in the Manual.

Mr. J. E. Willoughby:—My attention has been called to the fact that it is not necessary to bevel only one side of the nut, that side which is next to the angle bar. That suggestion should be incorporated as a modification of the drawing.

The President:—That will be taken care of. The question is now on the adoption of the Committee report.

(The question was put to vote and carried.)

Chairman Earl Stimson:—We will now have the pleasure of hearing from Professor Moore. He will tell us of the work that he has been doing on the transverse fissure research at the University of Illinois.

(For Prof. Moore's paper, see pp. 998–1012)

(First Vice-President A. R. Wilson assumed the chair.)

First Vice-President A. R. Wilson:—As can always be expected we get a very interesting report from this Committee, and particularly on the part that has just been presented by Professor Moore. The Committee is excused with the thanks of the Association (Applause).

SECOND PROGRESS REPORT ON THE INVESTIGATION OF FISSURES IN RAILROAD RAILS

By H. F. Moore

Research Professor of Engineering Materials, University of Illinois,
In charge of the Investigation

1. **Summary of Previous Work.**—The problem of the study of fissures in rails is quite typical of many problems in strength of materials in that it may be divided into two general divisions. The first division of the work seeks to answer the question: What will the materials stand? The answer to that is found mainly in laboratory tests.

The second division of the work seeks to answer the question: How much does the structure or the structural part have to stand in service? That, in general, is answered by field tests and quite largely by statistical information. The division of those two parts will be clear in this report.

Perhaps the main conclusion presented in the first bulletin of this investigation (Bulletin 376 of the AREA, June 1935) had to do with the first division: What will the material stand? And it may be summarized as follows:

The genesis of an internal fissure, transverse or otherwise, in a rail is nearly always, if not always, a shatter crack, in the center of the head of a rail. For the detailed evidence of that I refer you to Bulletin 376. However, it must always be borne in mind that nowhere near all shatter cracks develop into fissures. A shatter-cracked rail is not devoid of strength altogether; however, it has its strength weakened, sometimes by as much as 50 per cent. The search for the cause and for means of prevention of shatter cracks has been a major feature of the investigation. The theoretical shearing stress at the shatter-crack zone, due to wheel load*, the strength of cracked rail-steel specimens in fatigue tests, and the wheel load found necessary to develop fissures in shatter-cracked rail specimens tested in a repeated-rolling load testing machine,—all these fit into a consistent picture of the mechanism of the development of internal fissures in rails.

In a review of Bulletin 376 in the technical press there was one quite just criticism, to the effect that in that Bulletin sufficient emphasis had not been placed on the chemical and metallographic work which had been done. With that criticism was an expression that it was hoped that more research might be carried out to settle definitely the cause of the production of shatter cracks. Such research is indeed desirable but the search for the cause of shatter cracks is a very complicated problem in mill practice. It is not at all sure that any *one* cause explains all shatter cracks. During the investigation it seemed at first that in the silicon content of rail steel might be found an index to at least one important cause of shatter cracks. The data checked very nicely along this line until rails from one mill were studied which were high in silicon and yet unusually free from shatter cracks. The problem of determining the cause of shatter cracks seems to be a complicated problem of mill practice, and so far the clear determination of *all* the causes of shatter cracks has escaped detection.

However, there was opened up a field for the study of *prevention* of cracks by treatment during the cooling process. That was suggested by processes already in use on some of the Canadian steel mills in a commercial way, and processes in use in this country in an experimental way. The data which were reported were such as to seem to make the plan worth investigating. As reported in Bulletin 376, there was made a quite extensive study of methods of thermal treatment during the cooling of rails, and the laboratory study of preventive thermal treatment so far have checked results reported cracks as shown by laboratory etc. tests. In the Materials Testing Laboratory of the University of Illinois no internal fissures have so far been developed in any thermally treated test rail—either a control-cooled rail or a normalized rail. Of course, things occasionally happen in practice that laboratories never find out how to cause. But certainly there is evidence that the elimination of shatter cracks and consequently the probable immunity against the production of internal fissures seems to be very greatly helped by proper thermal treatment during cooling.

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* Rolling-load tests have shown that the spread of a fissure is *started* not by bending stresses, but by the complex localized stress directly under a wheel.

Another line of evidence which seems to support this statement is a study of the experience with the alloy steels, in which sometimes occur what are called "flakes". These flakes may be described as "first cousins" to shatter cracks, and controlled slow cooling was found to be the most effective method for preventing flakes in alloy steels.

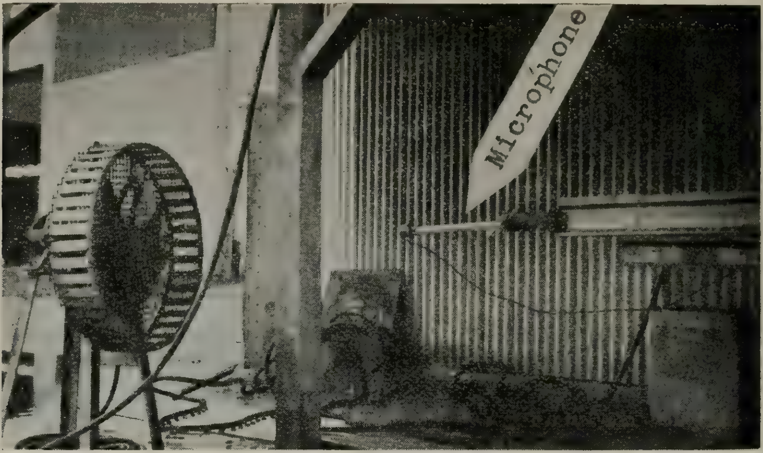
2. **Microphone Test for Cracking of Rails while Cooling** (under the direction of J. L. Bisesi and J. R. Trimble).—Going over, now, to work done since Bulletin in practice. All rails which had been control-cooled at the mills were free from shatter 376 was written, one of the first attempts was to see if there could be made some experimental studies in a mill of the range of temperature during which cracking occurred. The method of attack adopted was the use of a microphone attached to a cooling rail, a method suggested by Mr. F. M. Graham of the Pennsylvania Railroad, and tried in a very simple way in certain English rolling mills, and by the Lackawanna Steel Co.

Fig. 1 shows a 39-foot rail pulled from the hotbed, placed outdoors under slightly more severe conditions of cooling than those on the hotbed. A microphone attachment is clamped to the end of the rail, a fan is shown which in certain cases was used to give a blast of air on the rail.

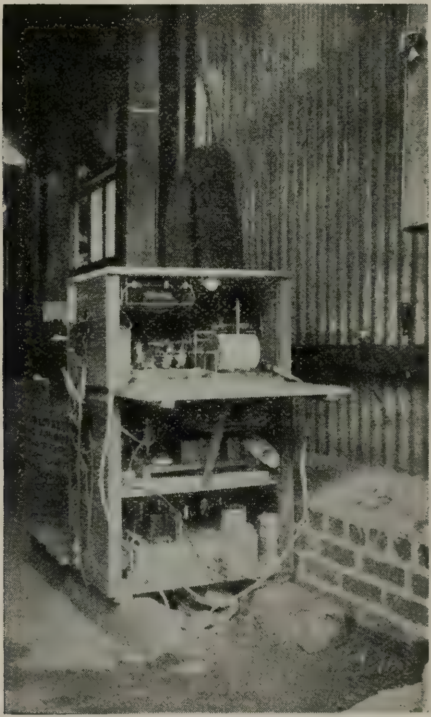
Amplifying tubes were used to amplify the current from the microphone to recorders and to the output meters used for checking the performance of the amplifier. The records were made on a moving tape by means of a pencil. Changes in current passing through the microphone, caused by slight sounds and then amplified, were impressed on the magnet operating the recording pencil, causing an offset in the record line. At regular intervals readings of rail temperature were taken, and the rail temperature corresponding to any offset in the record line could be determined.

It was not thought that this microphone test would serve as a non-destructive test for shatter cracks in rails as it would be a rather slow test and a rather complicated one. It was hoped, however, that it might be used to determine the range of temperatures during which the cracking occurred. However, it was found that in spite of attempts to filter out the sounds from the mill and noises of the rails grating over the supports, in this first test, there were so many sounds recorded which obviously were not cracks that we could not tell very much by this test. After considerable discussion a second test has been made in which, instead of merely one rail there were two rails, one the cooling rail and the other a cold "dummy" rail. Both rails were exposed to mill noises. It is presumed that mill noises were indicated on the record from both rails. Both rails were placed, not upon supports, but suspended from overhead, and there were damping pads in the supporting cables. The data from this second series of tests are now being reduced, and etch tests are being made to confirm or disprove the evidence of the microphone record.

3. **Acceptance Tests for Rails** (under the direction of N. J. Alleman).—To the test party no question has appeared more important in this rails investigation than the question of proper tests for detecting a shatter-cracked condition in a rail. Such tests may be divided into destructive tests of samples and non-destructive tests of rails. Destructive tests of samples include the drop tests (head-up and head-down), the bend test (head-down), and the etch test. The advantage of the destructive tests is that they



Microphone Set-up.



Amplifying and Recording Equipment.

Fig. 1.—Microphone Test for Cracking of Rails while Cooling at plant of Tennessee Coal, Iron and Railroad Co.

give positive, easily recognized results, and are not prohibitively expensive. The disadvantage of all destructive tests is—that they are tests of *samples*, and it is never possible to be sure that samples are thoroughly representative. That is especially troublesome with detection of shatter cracks in rails. There have been found rails in the same heat, some shatter-cracked and others not shatter-cracked. There have been found rails in which some parts of the length are shatter-cracked, other parts not shatter-cracked. However, it should be remembered that destructive tests of samples, while not perfect, are, if carefully performed, far better than no tests at all.

Considerable study, with the testing of many rails, has been given to the drop test and the bend test and there is presented, as the opinion of the test party, the following: As a detector of shatter-cracked rails the common head-up drop test is practically useless. Shatter-cracked rails, many of them, will pass this test without any trouble. The drop test head-down is somewhat better. Still, a good many rails shatter-cracked would withstand one blow head-down. The repeated drop test, counting the number of blows, is probably still better, but has two serious disadvantages. In the first place, the blow is delivered in increments of about 40,000 foot-pounds of energy to the rail. It is impossible to distinguish between a rail which stands a little above 100,000 pounds and one which stands a little below 120,000, and that means the test is not at all sensitive.

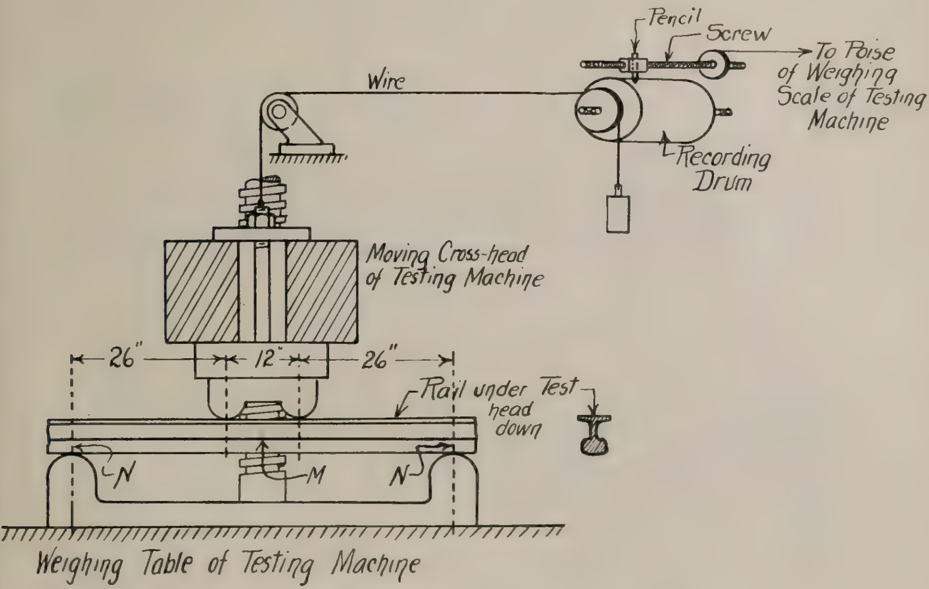

Pencil
Screw
To Poise of Weighing Scale of Testing Machine
Wire
Recording Drum
Moving Cross-head of Testing Machine
26"
12"
26"
Rail under Test head down
N
M
N
Weighing Table of Testing Machine

FIG. 2.—Diagram of Test Rig for Bending Tests of Rails.

The second and still more serious objection to the repeated drop test is that after the first blow the rail is distorted, bent and twisted,—and succeeding blows do not strike the rail in at all the same way,—do not stress just the same parts; this is especially noticeable in a head-down drop test.

The bend test, proposed I think by the Pennsylvania Railroad and the Illinois Steel Company back before the war, is described in Bulletin 376. The arrangement for the test is shown in Fig. 2. The test used was a rather slow bend test, because of the power and speed limitations of the 600,000-lb. testing machine used. The test is a head-down test, with the load at two symmetrical points in the span, giving a space of about 12 inches where the rail is under uniform bending moment and stress. The load on the rail is recorded on a drum attached to the weighing beam of the testing machine. The deflection is recorded by the revolutions of the drum, and the result of the test is a load deflection diagram, as shown in Fig. 3. The deflections are large, sometimes as high as eight or nine inches. The area under a load-deflection diagram is measured, and is a measure of the energy required to fracture the rail. In the bend test the energy put in is under very good control, and the whole test is much more sensitive, quantitatively, than the repeated drop test.

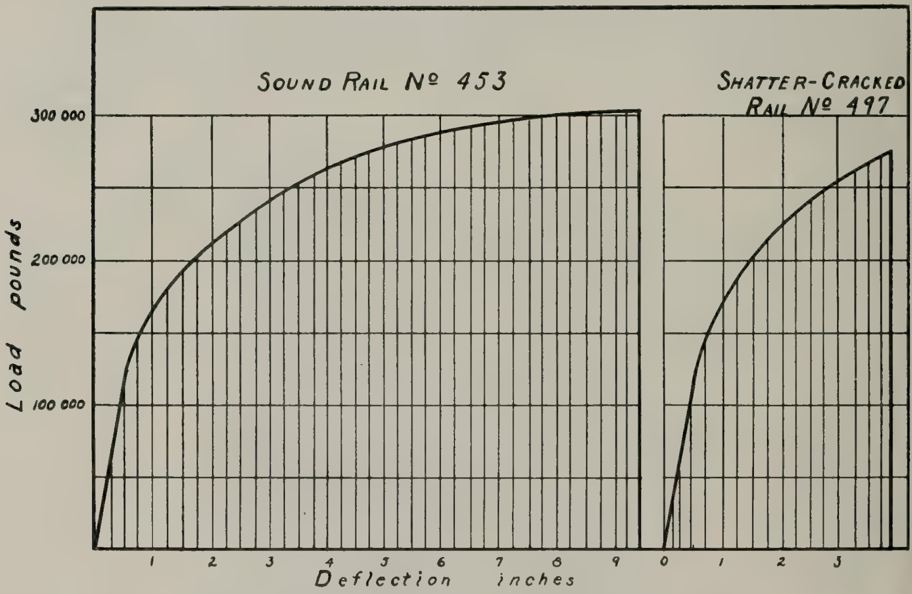


Fig. 3.—Load-Deflection Curves—Bending Tests on Rails.

Fig. 3 shows typical records for (1) a rail without shatter cracks (as shown by the etch test) and (2) one with shatter cracks. This test has not rated 100 per cent as a detector of shatter-cracked rails, but it has given better results than any of the other tests which have been tried.

Fig. 4 shows typical fractures under the bend test. The lower rail was a sound rail free from shatter-cracks, and the upper one is a shatter-cracked rail. Of course, the question at once arises: "What is the effect of speed of loading?" At speeds which are developed in the drop test and others, the speed effect does not seem to be very great. It usually takes more energy to break a rail suddenly than with a slowly applied load, but with a series of rails, the relative values would probably be approximately the same whether the drop or the bend test were used.

A confirmation of this result is found in some work done by the late Mr. Petrenko of the National Bureau of Standards, who studied the energy required to break notched specimens, using a slow bend test and an impact test. While there was not a "one to one" correspondence in energy by any means, either test could be used fairly satisfactorily to show the relative amount of energy required to break a specimen. The bend test seems to show under better controlled conditions the same sort of thing that the drop test does, and in addition gives load values.

In the metallographic work (under Mr. Cramer) there have been made a good many hundreds of etch tests, and of metallographic examinations. The cost of the etch test is not prohibitive, although cutting the rail head into several slices costs a good deal in hack-saw blades. The etch test is not a quantitative test. If the etch test were used as an acceptance test, probably there would be involved questions of tolerance of longitudinal shatter-cracks, and of shatter-cracks deep in the rail. Longitudinal shatter-cracks are in all probability less disastrous than are transverse shatter-cracks, and shatter-cracks deep down in the rail head than shatter-cracks near the surface. It seems inadvisable to suggest any specifications for etch tests or bend tests at this time.*

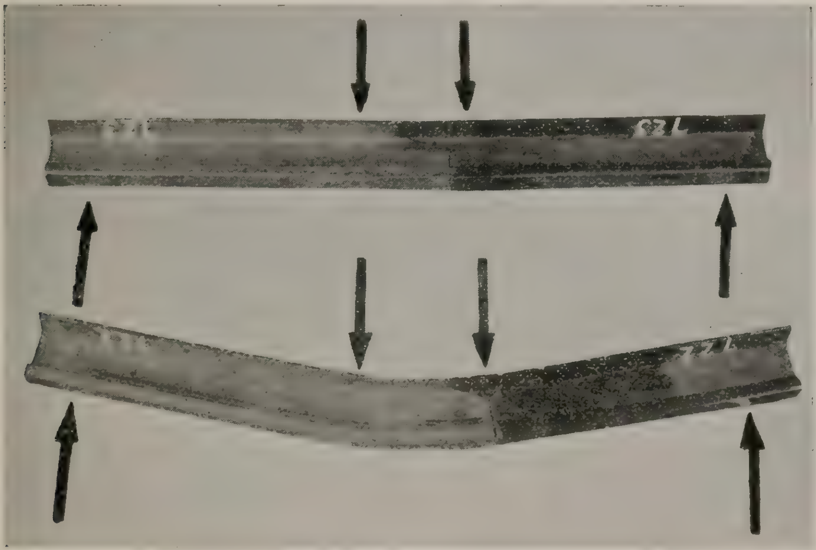


Fig. 4.—Rails after Bend Test. Upper rail showed shatter cracks in the etch test. Lower rail showed no shatter cracks in the etch test.

It is the present opinion of the test party that if today we had to choose a test which would be of value in detecting shatter-cracked rails, we should recommend the head-down bend test with auxiliary etch tests in case of any doubt. The bend test would require a 500,000-lb. testing machine powered for high speed tests.

Of course, the ideal test for shatter-cracks would be a non-destructive test applied to every rail. While no such test has been discovered which is sufficiently sensitive to detect shatter-cracks in a newly-rolled rail, a non-destructive test would be so useful and

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* In the etch tests a 50 per cent water solution of hydrochloric acid at a temperature of 200 deg. Fahr. was used. The specimen was etched for 30 minutes.

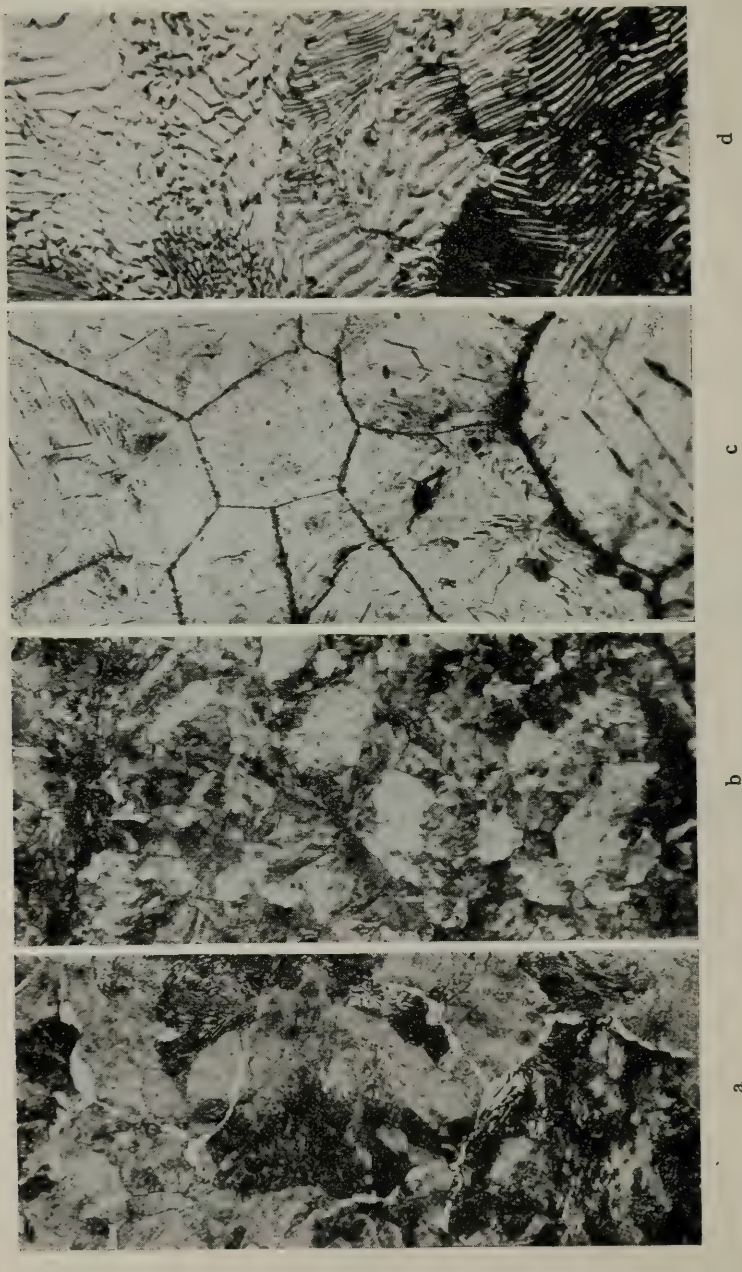

FIG. 5.—Typical Crystalline Structures in Rail Steel.

(a) Excess ferrite, magnification 200x, rather rare structure.
(b) Normal structure, almost entirely pearlite, magnification 200x.
(c) Excess cementite, magnification 200x, rare structure.
(d) Normal structure, magnification 2000x.

so important that it is felt that further research is worth while. The quantity of metal around the shatter-crack or adjacent area which may become cracked is very minute, compared with the volume of the rail, probably a fraction of one per cent. A reliable non-destructive test must show positively rather small variations in this one-tenth of one per cent of volume. However, recent tests have been proposed and tried abroad, using an extremely high frequency wave, "super-sonic" waves, as they are called.

4. **Metallographic and Chemical Studies** (under direction of R. E. Cramer).—Mention has been made of metallographic and chemical tests. These have involved a large amount of routine work. There have been made hundreds of tests. Hundreds of chemical analyses have been studied. About a thousand micrographs have been made, and many macrographs and X-ray diffraction patterns. So far no outstanding features of either chemical composition or metallographic structure have been associated clearly and definitely with shatter cracks.

Fig. 5 shows three typical structures which were found in rail. The one at the left, (a), is rail in which there is a little excess ferrite, shown by the white line of ferrite outlining the boundaries of the crystalline grains. At (c), is shown a rather unusual structure for rail steel in which there is an excess of cementite. The grains are outlined by cementite boundaries. The micrograph (b), is the ordinary structure of rail steel,—practically pure pearlite; at (d) this structure is shown at about 2000 magnifications.

Some studies have been made, mainly from current metallurgical literature, of gases in steel. It seems that the gases which *remain* in rail after it is cooled are not of any great importance, but the gases which may cause trouble are those which escape—or attempt to escape from the rail while cooling takes place. A similar condition holds for residual stresses. The stresses which have been measured in rail after it has been cooled are appreciable, but not enough to explain cracking, and in most cases have been of the wrong sign to start cracking in the center of the head. However, those stresses have no relation which we can discover with the very much higher stresses which may exist, especially over localized areas, while the rail is cooling. Obviously it would be a very difficult problem to measure the stresses while the rail is cooling.

5. **Tests of Rail Steel at Low Temperature,** (under the direction of H. B. Wishart).—There is in progress a series of tests of rail steel specimens at low temperatures. The tests are being made in the cold room of Wright Field, U.S. Air Service, Dayton, Ohio. Some of these tests were reported in Bulletin 376, showing an increase in strength factors and a decrease in ductility factors at low temperatures. The object of these tests is to get a basis for distinguishing between (1) embrittlement of steel and (2) track conditions as contributing causes for the increased failure of rails in cold weather, and in days immediately succeeding cold weather. At the present time, with the very generous cooperation of the United States Air Service at Wright Field, tests are going on with the special purpose of studying the effect of occasional heavy overloads on rail steel at temperatures as low as 40 deg. below zero Fahrenheit.

6. **Tests of "Batter" of Rail at Joints,** (under the direction of N. J. Alleman).—Fig. 6 shows the arrangement of a rolling-load machine for a batter test on a rail joint. The specimen, T, supported with a rail joint at mid-span, and at the left end of T is a clamp, C, with a little dowel pin D on it. To that dowel can be attached a micrometer measuring device, shown in Fig. 7 for taking "soundings" over the worn surface of the rails. The micrometer M can be moved longitudinally and crosswise. Contour lines of the surface of the rail heads can be plotted for any number of passages of a given load. Preliminary tests of batter are in progress and Fig. 8 shows one test result.

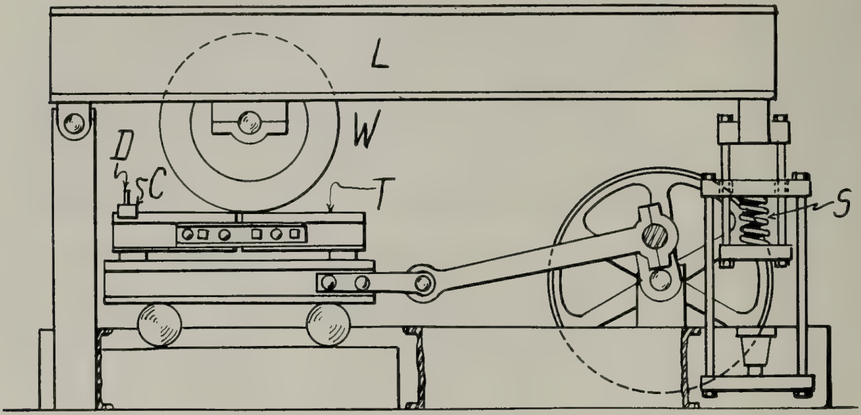

FIG. 6.—Arrangement of Rolling-Load Machine for Batter Tests.

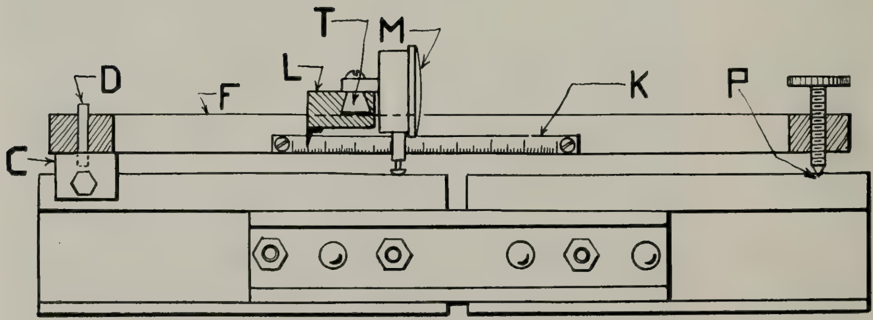

FIG. 7.—Micrometer for Measuring Batter of Rail-Joint Specimen.

7. **Field Tests for Wheel Loads in Service,** (under the direction of H. R. Thomas and N. H. Roy).—As was noted in the opening paragraphs of this report, the second main division of the investigation is the study of the behavior of rails in service. What wheel loads do the rails have to withstand in service? In Fig. 9 are shown the results of field tests for wheel loads. This graph shows the same data as is shown in Fig. 9 of Bulletin 376 (tests on the Baltimore and Ohio Railroad north of Dayton, Ohio, and on the Pennsylvania Railroad near Coatesville, Pa. In addition results are shown for tests on the New York Central Railroad east of Rome, N.Y. In Fig. 9 the abscissas show the magnitude of wheel load, and the ordinates show the percentage of total number of wheel loads. On the Baltimore and Ohio and the Pennsylvania the track was subjected to heavy ore and coal traffic. On the New York Central the traffic was mixed freight with a large proportion of refrigerator cars, and a comparatively small number of heavily loaded coal cars. The diagrams shown in Fig. 9 are based on about 36,000 wheel loads at Coatesville, 53,000 wheel loads at Dayton, and 25,000 wheel loads at Rome.

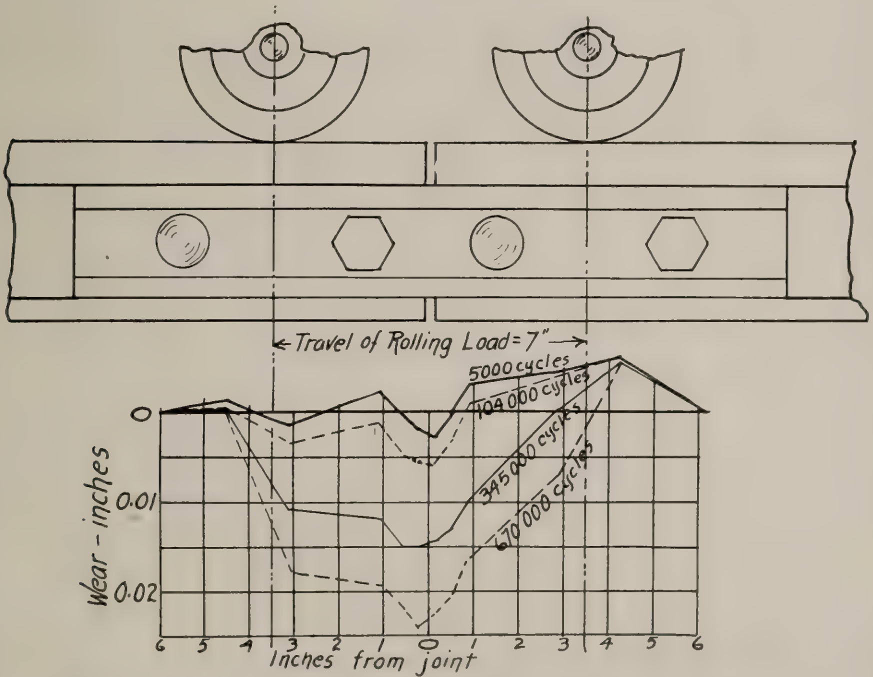

FIG. 8.—Rolling Load "Batter" Test Rails 495 and 499 130-lb. Rails Santa Fe 4-Hole Bars 350000-in. lb. Max. Moment 75000-lb. Wheel Load.

On the New York Central location the frequency of high wheel loads is obviously less than on the other two locations—one 30,000-lb. wheel load per thousand passing wheels as against one 40,000-lb. wheel load per thousand passing wheels for the other two locations.

In interpreting the diagrams shown in Fig. 9 it should be remembered that the values shown are the average values for some ten instruments at a location. Now the frequencies of high wheel loads at some *one* of these instruments might be several times the average frequency for the whole location. Consequently there might occur a development of a transverse fissure sooner than the average results would indicate.

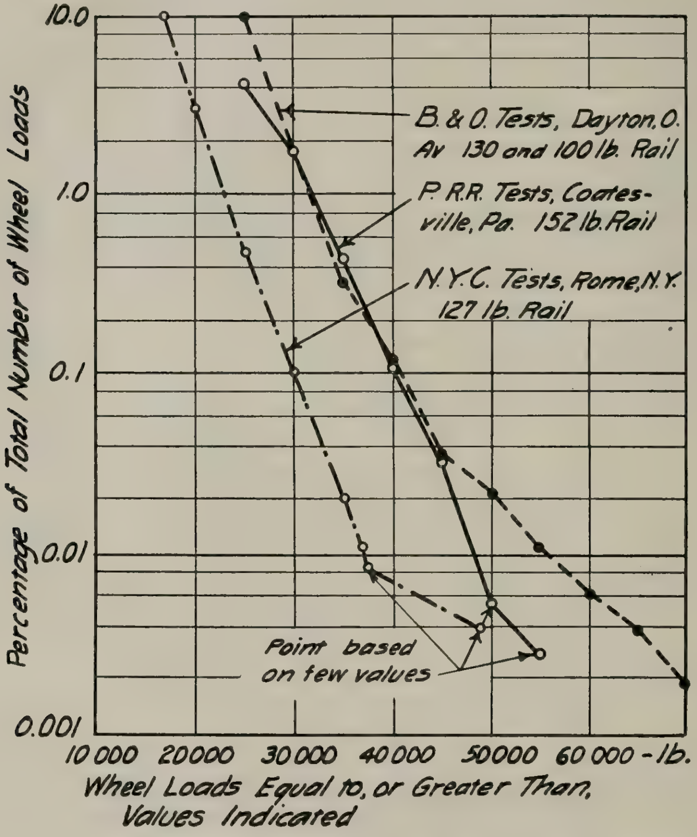

FIG. 9.—Load-Frequency Diagrams for Field Tests at Three Locations.

At the location near Rome on the New York Central, there was run a series of tests, the results of which are interesting. These are shown in Fig. 10. The graph furthest to the left is the one shown in Fig. 9. The center graph shows results on a 105-lb. rail, located at Greenway, N.Y., a location where the track was less well maintained than the track with 127-lb. rail near Rome. The graph at the right shows results on a short length of 105-lb. rail, located on a bridge east of Rome. This location was picked out as a sample of stiff track. It will be noted that at both the Greenway and Rome locations the frequency of high loads is less than at the Dayton and Coatesville locations (Fig. 9), and also less than on the bridge. This does not justify the conclusion that transverse fissures are more likely to occur on bridge tracks than on ballasted track. That is another story. The *rate of development* of transverse fissures is largely dependent upon the *bending* stresses, so that even if more transverse fissures were *started* on the stiff bridge track, probably they would not *develop* as fast as on ballasted track on account of the low bending stress. Furthermore, this is just one bridge,—and it would be quite unwise to draw any general conclusion. Results on a bridge with ballasted deck might be quite different. This bridge location was selected merely as an example of stiff track.

Another indication of the stiffness of track at any location is given by the ratio of wheel load to bending moment. In a very stiff beam with a short span, the ratio of load to bending moment will be high. In Fig. 11, the upper graph shows this ratio of wheel load to bending moment at different lengths along the test location on the bridge. The lower graph shows the ratio at the flexible-track location at Greenway. The same result is shown in Fig. 10 by a comparison of the graph for the bridge track and that at Greenway.

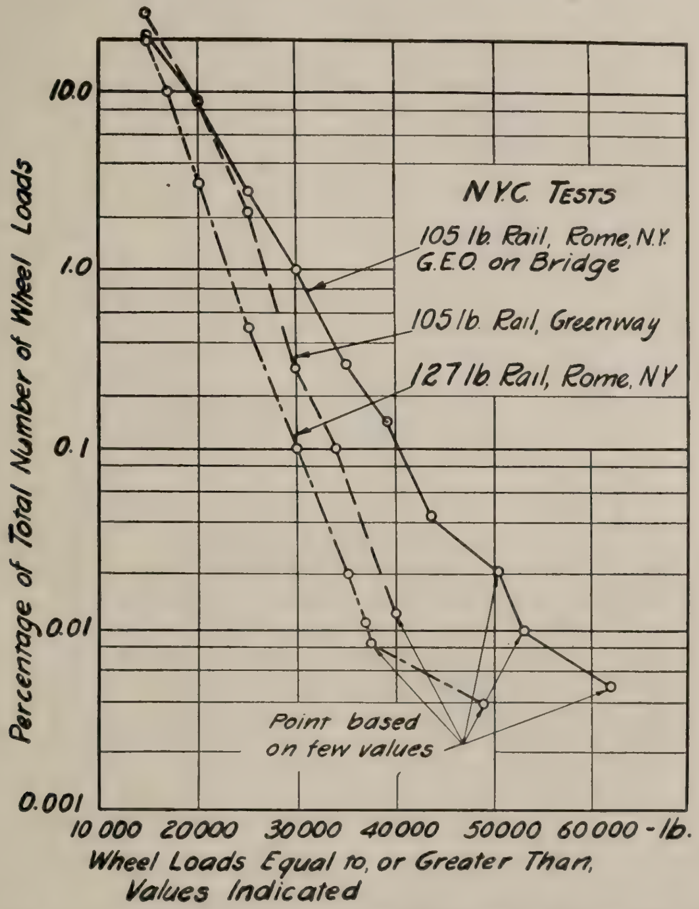

Fig. 10.—Load-Frequency Diagrams for Field Tests of Sections of Track with Different Stiffness.

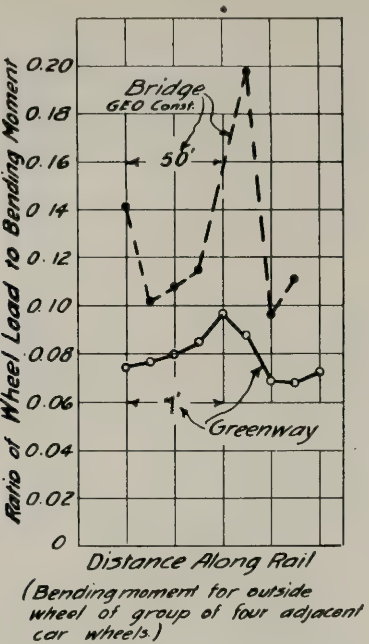

FIG. 11.—Load:Moment Diagram. For Two Test Locations Having Different Stiffness. 105-lb. Dudley Rail.

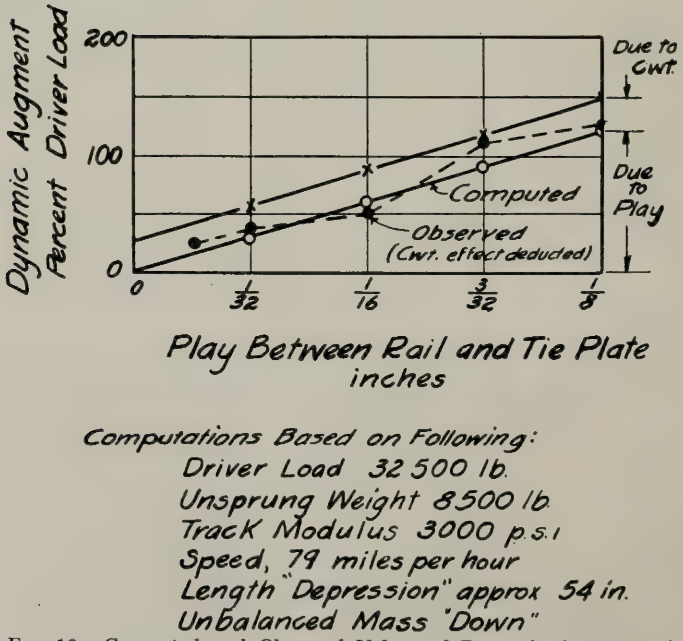

FIG. 12.—Computed and Observed Values of Dynamic Augment of Driver Load Due to Play Between Rail and Tie.

Fig. 12 is a study of the increase of wheel load (dynamic augment) carried by unbalance of counterweight as compared with the increase accompanying play between rail and tie. It will be noted that, for any given speed, as the amount of play in rail support increases, the dynamic augment due to this play may become greater than that due to unbalance of counterweight. The play between rail and tie plate was measured with a wedge gage.

Looking over the data on wheel loads obtained so far it seems that in the speed ranges of trains below 25 m.p.h., flat spots on wheels are very prominent as a cause of high wheel loads. In the range of 40 to 50 m.p.h., hard spots in the track seem prominent, and in the range of 60 m.p.h. and above out-of-round wheels, unbalance in counterweights and abnormally high track play seem to loom up as important factors.

The plans for the future field tests during this year include the plan for testing on a typical location on a Western railroad with a traffic condition and structure typical of Western roads, probably in the Great Plains region. Arrangements are being entered into with one of the Western railroads for such a location.*

In field tests the principal emphasis has been laid on wheel loads, because, as was shown in Bulletin 376, it is wheel load rather than bending moment which *starts* the spreading of a fissure. The actual measurements taken are measurements of strain (tensile or compressive) in the flange of the rail. From this strain bending moment can be computed, and, knowing the track constant (track modulus) from results of slow speed tests, the formulas developed by Professor Talbot can be used to determine wheel load. This involves the assumption that the rail takes the same *kind* of an elastic curve under a slowly applied load and under a rapidly applied load. Tests of a steel rail under impact bending loads have been carried on in the University of Illinois Materials Testing Laboratory by Dr. R. N. Arnold, a graduate of Glasgow and Sheffield, who has been spending two years in this country on a Commonwealth Traveling Fellowship. Dr. Arnold's results show that under very rapid loading the inertia of the beam makes it act as if partially restrained at supports, and that the load necessary to cause a given tensile stress is *higher* than would be indicated by the method just indicated. However, it is believed that the reporting of wheel loads as has been done in Bulletin 376 and in this report is justified for two reasons. First, actual wheel loads are probably *higher* than those we have reported, and as the reported values are high enough to demand attention it seemed wise to report them. In the second place under "impact" loads on track the duration of the high loads is very short—of the order of 0.001 second. It is a fairly well-established fact that under very high speed of application of load steel requires greater stress to fracture it than under slow application of load (the "skating over thin ice" effect). So there is some tendency for the effect of higher wheel loads than have been reported to be offset by the increased strength of rail steel under rapid application of stress.

8. **Importance of Maintenance of Track and Rolling Stock.**—Laboratory tests indicate that repeated wheel loads of 40,000 pounds or over may spread shatter cracks to surface fissures, in either a heavy rail or a light rail. Loads of that magnitude certainly occasionally occur in ordinary service on well maintained track. Suppose that the improved methods of rail manufacture prove 100 per cent perfect. During the next ten years there will still be thousands of shatter-cracked rails in existing railroad track. For the immediate future, reduction of fissures, no matter how much the product of rail mills may be improved, will demand a high degree of cooperative work between track

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* Since the oral presentation of this report there have been carried on field tests on the section of track laid with 110-lb. test rails on the A. T. & S. F. Ry. near Matfield Green, Kansas.

maintenance engineers and rolling stock maintenance engineers. Improved maintenance could not be expected to eliminate fissures, but it could be expected to reduce markedly the number which occur per year.

9. **Acknowledgment.**—This investigation is a joint investigation sponsored by the Rail Manufacturer's Technical Committee and the Association of American Railroads, and carried on with headquarters in the Materials Testing Laboratory of the University of Illinois as a part of the work of the Engineering Experiment Station of that university. The work in the Materials Testing Laboratory has been under the general administrative direction of Dean M. L. Enger, Director of the Engineering Experiment Station, and Prof. F. B. Seely, head of the Department of Theoretical and Applied Mechanics.

The sponsors have maintained contact with the test party through an Advisory Committee, and acknowledgment is here made to that committee for their most valuable assistance in suggesting test methods and fields of study and in their helpful and constructive criticism of the work of the test party.

The members of the Advisory Committee are:

For the Association of American Railroads—Rail Committee:

Earl Stimson, Chief Engineer Maintenance, B. & O. Railroad, *Chairman.*
W. C. Barnes, Engineer of Tests, Rail Committee, Am. Ry. Eng'g. Ass'n.
A. F. Blaess, Chief Engineer, Illinois Central System.
C. B. Bronson, Inspecting Engineer, N. Y. C. Railroad.
E. E. Chapman, Engineer of Tests, A. T. & S. F. Railway.
Robert Faries, Asst. Chief Engineer Maintenance, Pennsylvania Railroad.
J. V. Neubert, Chief Engineer Maintenance of Way, N. Y. C. Railroad.
G. J. Ray, Vice-President and General Manager, D. L. & W. Railroad.
W. P. Wiltsee, Chief Engineer, Norfolk & Western Railroad.
Louis Yager, Asst. Chief Engineer, Northern Pacific Railway.

For the Rail Manufacturer's Technical Committee:

F. W. Wood, 2429 Keyworth Ave., *Chairman.*
John Brunner, Mgr., Dept. of Metallurgy and Inspection, Illinois Steel Co.
O. U. Cook, Inspecting Engr., Tennessee Coal, Iron & Railroad Co.
E. F. Kenney, Metallurgical Engr., Bethlehem Steel Co.
L. S. Marsh, Mgr., Dept. of Inspection and Metallurgy, Inland Steel Co.
C. W. F. Rys, Asst. to President, Carnegie Steel Co.
W. A. Maxwell, Jr., Vice-Pres., Colorado Fuel & Iron Co.

DISCUSSION ON TRACK

(For Report, see pp. 463–507)

(Vice-President A. R. Wilson in the chair.)

Mr. C. J. Geyer (Chesapeake & Ohio):—The report of the Committee on Track is in Bulletin 383, page 463. The first subject, "Revision of Manual," is in two parts as Appendix A. The first part begins on page 465 and ends with the first part of page 470. We have no division between these two parts in the Manual as printed with the exception of the paragraph division. On the first part of the revision of the Manual, the report will be presented by Mr. W. G. Arn, Chairman of the Sub-Committee.

Mr. W. G. Arn (Illinois Central):—The Committee recommends that there be two groups of definitions—one for the Manual, and one for the trackwork portfolio. That all definitions included in the Manual itself be segregated into a chapter on definitions in alphabetical order at the back of the book. That those definitions referring particularly to trackwork portfolio plans be printed in the portfolio only.

That the following changes be made: Insert as the first paragraph in chapter: "The AREA Portfolio of Trackwork Plans, Specifications, and Definitions, although a separate volume, is a part of this Manual."

Definitions:—In line with the general idea that was given to all committees, it is recommended that the following definitions be omitted: Alinement, Branch Line, Closure Rails.

That the following definitions be changed as shown. In the definitions that are printed here, where there is no change from that as printed, I will merely read the term to be defined.

"Crossing (Track).—A structure, used where one track crosses another track at grade, consisting of four connected frogs." Crossover, Double, or Scissors. "Elevation (of Curves) (Super-elevation).—The vertical distance that the outer rail is above the inner rail."

"Foot Guard; Gage Line; Gage (of Track); Guard Rail; Joint Bar (use Rail Committee's definition); Joint Drilling (use Rail Committee's definition); Spot Board; Surface (Track); Switch; Tie Plate; Turnout; Wye."

Maintenance of Line:—(a) Tangents, (b) Curves; Use of Easement Curves (Spirals). "Easement curves should be used with all curves having an elevation of two inches or more. When elevation is less than two inches, the use of easement curves should be a matter of judgment, considering the amount of offset, speed and other features.

"Length of easement curves should be based on the maximum allowable speed and should not be less in length than that which will cause a rise of not more than 1½ inches per second for the maximum speed. If physical conditions permit, the length of easement curve should be based on a rise of not more than 1¼ inches per second.

"Curve elevations should be run out uniformly over the easement curve."

Mr. J. B. Jenkins (Baltimore & Ohio):—The second paragraph recommends spirals of a length which will cause a rise of not more than 1½ inches per second, or not more than 1¼ inches per second, if physical conditions permit.

The last paragraph, which has not been read yet, recommends the retention of the graph and text on page 203 of the Manual, except paragraph 3.

The two recommendations are inconsistent one with another, but the inconsistency may be removed by changing "1½ inches per second" to "2.2 inches per second," retaining the last sentence as written.

The rigid adherence to a maximum rise of not more than 1½ inches per second would either place an unwarrantable restriction on speed, or would render it well-nigh impossible to use spirals where the alinement is principally curved and the tangents are short. The 2.2 inches used as a basis for fixing the minimum length of spiral was not arbitrarily assumed, but was the result of an exhaustive investigation, and was intended to represent that rate at which the disadvantage of using too short a spiral would equal the alternative disadvantage of increasing the degree of a speed-limiting curve and was based upon the accepted principle that any short spiral is better than none.

I therefore move that the second paragraph under "(b) Curves; Use of Easement Curves (Spirals)" be changed to read:

"Length of easement curves should be based on the maximum allowable speed and should be not less in length than that which will cause a rise of not more than 2.2 inches per second for the maximum speed, such minimum length to be used only where an increase in length would increase the degree of a speed-limiting curve. If physical conditions permit, the length of easement curve should be based on a rise of not more than 1¼ inches per second."

Mr. W. G. Arn:—In view of the inconsistency which Mr. Jenkins has brought out, I think the Committee will have no objection to accepting that revision, if there is no objection from the floor.

First Vice-President A. R. Wilson:—We will leave that in the hands of the Committee.

Mr. W. G. Arn:—Continuing under "Maintenance of Line": "If no easement curve is provided the elevation should be run out on the tangent, using the full elevation at point of curve.

"Easement curves should be used between curves of different degrees and changes of elevation should be effected just as between curves and tangents.

"Any form of easement curve is satisfactory which is of the general form of a cubic parabola. Spirals. Notation."

Mr. J. B. Jenkins:—I would like to make a little further comment on the parenthetical recommendation: "(Retain the graph and text on page 203, except paragraph 3)."

To make the spirit of the text following the graph conform with the new recommendation of the Committee, that is, "If physical conditions permit, the length of easement curve should be based on a rise of not more than 1¼ inches per second," I would ask the Committee if they would accept the following amendment to the text beneath the graph to read: "Minimum Length of Easement Curve."

Mr. W. G. Arn:—As an addition?

Mr. J. B. Jenkins:—This is a substitution for the text underneath the graph, and it would eliminate the sub-paragraph headings there shown. It would read: "Minimum Length of Easement Curve.—For all curves which are liable to limit the speed of trains, the minimum length of spiral should equal that indicated on the line marked 'Elevation = 8 inches.' For minor curves the minimum length should be that indicated by the diagram for the highest permissible speed.

"Spirals longer than the minimum should be used except where such increase in length would adversely affect the degree of speed-limiting curves. The amount of increase in length should be governed by the cost of construction or reconstruction and the effect on degree of curve. An increase of not less than 76 per cent over the minimum length is recommended where physical conditions permit."

The reason for the 76 per cent is to make it conform to the recommended 1¼ inches. The maximum of 2.2 inches and 76 per cent increase would give the 1¼.

I would also call attention to some other matters in connection with the graph.

The graph has frequently been misinterpreted as indicating the highest permissible speed for given lengths of spiral instead of the minimum length of spiral for such speed, as intended. The liability of making this error was increased by the printer of the Manual inadvertently turning the graph wrong side up so that "Highest Permissible Speed in Miles per Hour" appears at the top of the graph instead of "Minimum Length of Spiral in Feet."

The graph should be righted and a note should be added to prevent its misinterpretation.

I would suggest that the following note be added in the vacant space in the graph in order to prevent such misinterpretation of its use:

"The 'Highest Permissible Speed in Miles per Hour' is the basis for determining the length of spiral but is not conversely the highest speed permissible for a given spiral."

I would ask if the Committee would please accept those changes.

Mr. W. G. Arn:—This graph and note have been in the Manual for a long time and these objections were not brought up. The Committee ought to have time to consider this more in detail before agreeing to that because nothing of this kind was brought up for consideration at the meeting in which this was agreed upon.

Mr. J. B. Jenkins:—The graph as adopted in convention was not the same side up as it is now.

Mr. W. G. Arn:—I see no objection to righting that error, but he has given a good deal of matter for consideration and I think the Committee ought to have time to consider that and that would carry it over until next year.

First Vice-President A. R. Wilson:—I think they certainly ought to take under consideration Mr. Jenkins' recommendations to see whether they can concur before reporting at this time.

(The meeting adjourned for the Association luncheon, and reconvened at 2:30.)

Mr. W. G. Arn:—We were down to the subject of "Spirals" on page 466 of Bulletin 383.

Following "Spirals" is "Maintenance of Surface." The formulas which have been used are for the superelevation of curves in the old Manual and the arrangement shown here is merely a consistent rearrangement of the material. That carries down to approximately the middle of page 467, at which point the reference to the table is shown. This table takes up the following page, page 468. That, in the Manual, would be inserted at that point.

Then comes the question of the proper method of tamping. Some changes are made in the text of the Manual and under No. 1 it is intended to substitute the word "dirt" for "earth or clay," which are now in the Manual.

Mr. J. B. Jenkins:—I have some remarks to make on what has just been covered by the Committee. On page 468, "Speed Table for Curves", the following changes in the Committee's report should be made, that is, in the table itself. In the title strike out "Where center of gravity is 84 in. above the top of rail," as the table applies equally to all heights of center of gravity, and change the last line in the title to read "M = Moderate Speed = Speed at 3 in. unbalanced elevation."

In the third paragraph in the text below the table strike out the second sentence, "The limits as shown will also serve for use on any lower height of center of gravity, as the speeds for 3 in. unbalanced elevation for 84 in. height center of gravity are approximately the same as for 2¼ in. unbalanced elevation for 54 in. center of gravity." The statement is untrue as the speeds for 3 in. unbalanced elevation for an 84 in. height are identical with the speeds for 3 in. unbalanced elevation for all other heights of center of gravity.

Add to the fourth paragraph: "but for best riding conditions about one-half inch less elevation should be used," so that the paragraph will read: "For traffic at one speed equilibrium elevation is the most economical but for best riding conditions about one-half inch less elevation should be used."

Then change the next to the last paragraph to read: "For a preponderance of slow traffic where schedules make it necessary and conditions of track permit speeds resulting in about 5½ in. unbalanced elevation for 84 in. height of center of gravity or about 8½ in. unbalanced elevation for 54 in. height of center of gravity, and proportionately for other heights, may be used."

I would ask the Committee if they would accept these changes.

The unbalanced elevation last mentioned would keep the resultant forces within the limits of the middle third, that is, never more than one-sixth gage width away from the center line of track. Within the last week I have observed, without measurement, unbalanced elevation on moderately high-speed trains. The coffee in a cup three inches wide stood on one side one and one-half inches higher than on the other, steadily, not vibrating, which would mean one in six, or in 57 in. it would mean more than 9 in. unbalanced elevation, with nothing spilled off on the dining car table. People walking in the aisle had no difficulty. It might have been just beyond the point of pleasantest riding but with no serious discomfort, at that. I think the idea of labeling 3 in. unbalanced elevation the maximum elevation is all wrong. That means that you cannot elevate your track more than 3 in. because as soon as you get 3½ in. and stop the train you have 3½ in. unbalanced elevation.

Mr. W. G. Arn:—Some of the points mentioned by Colonel Jenkins were considered by the Committee and the methods of figuring apparently are different on some roads, because on some roads, those that have the high-speed trains, they figure this 2½ in. unbalanced elevation at 54 in. center of gravity to be approximately the same as for the 84 in. So there seems to be a difference of opinion.

As for the maximum speed, we have under the title in the table the parenthetical note "(not limits of safety)."

It was not the intention in recommending this table that this be taken as a limit of safety or the maximum speed that could be used, but the maximum speed that was recommended for general use, considering all reasonably well maintained track.

The Committee will be glad to take under consideration all the points raised by Colonel Jenkins but without study on some of them I do not think that the Committee as a whole would be willing to agree to all those changes.

Mr. J. B. Jenkins:—In regard to the statement that speeds for 3 in. unbalanced elevation for 84 in. height center of gravity are approximately the same as for 2½ in. unbalanced elevation for 54 in. center of gravity, I do not think that can be a matter of opinion at all. It is simply a matter of mathematics. When the resultant force is 3 degrees from the perpendicular to the track, you have 3 in. unbalanced elevation, and the angle from the perpendicular certainly cannot be affected in any way by the height.

There is another matter. The Committee recommends that certain graphs be eliminated from the Manual. It mentions three graphs, on pages 232 and 233, and the table on page 231. It fails to mention another graph in the same series on page 234.

The graphs on pages 232 and 233 of the Manual, entitled "Speeds of Trains on Curves—Resultant Through Edge of Middle Third—Height of Center of Gravity = 84 inches" and "Speeds of Trains on Curves—Unbalanced Elevation = 3 inches—All Heights of Center of Gravity," are graphical representations of mathematical facts and should be permanently retained either in the Manual proper or by reference therein to the Proceedings in which they may be found.

The table on page 231 of the Manual entitled "Relative Speeds Through Level Turnouts," and the graph on page 234 entitled "Speeds of Trains Through Level Turnouts," are conclusions based upon the assumption that the motion through a switch point is equivalent to the motion through a curve of equal angle and of length equal to that of the switch point. The conclusions in this table and graph are questionable only to the extent that the assumption is questionable. The assumption, however, is the same as that upon which the adopted tables of turnout leads and all adoped turnout plans are based. This table and graph should therefore be retained in the same manner as the graphs on pages 232 and 233 until such time as a better assumption can be made, which would involve a complete revision of the tables of turnout leads and of the plans of turnouts.

I therefore move that the text and table on page 231 and the graphs on pages 232, 233 and 234 be retained by reference thereto in the Manual.

Mr. W. G. Arn:—While the matter is given in the Bulletin as outlined by Colonel Jenkins, at a subsequent meeting of the Committee an opinion was expressed that the table for speeds through turnouts should be further considered and that these diagrams which he refers to here on page 469 of the Bulletin, as being eliminated be retained until the further study was completed. Therefore, the first brief paragraph on page 469, to which he refers, is going to be eliminated.

First Vice-President A. R. Wilson:—And you withdraw that from your report?

Mr. W. G. Arn:—Yes, sir. That would retain them in the Manual as he wishes.

First Vice-President A. R. Wilson:—There was a motion before the convention that was seconded. I assume that the statement by the Committee Chairman, in agreement with Colonel Jenkins, will dispose of that motion. If I hear nothing to the contrary, it will be so ordered.

Mr. J. B. Jenkins:—Inasmuch as the Committee has withdrawn the portion of its report calling for the elimination of those in the Manual, I of course withdraw the motion.

Mr. W. G. Arn:—On "Proper Method of Tamping," paragraph No. 1, which was formerly "Earth or Clay," the Committee recommends a change to "Dirt," with a slight revision but the substance is much the same as given.

On No. 2 there would be no change.

On No. 3, which applies to "Burnt Clay Ballast," it is the recommendation that this be omitted entirely, there being practically no new ballast of that kind used.

On No. 4, "Broken Stone or Slag," there was an omission under "Tools." That should read: "Shovel, tamping pick, ballast fork or tamping machine."

Next is "Maintenance of Gage," page 467. The substance as given, I guess, should be read:

"(a) Appliances and Methods Used to Prevent Spreading of Track and Canting Rails on Curves.

"1. Tie plates with shoulders are recommended on all treated ties, on all curves and in all other cases where economy in maintenance justifies.

"2. Where tie plates are not used, the outside of both rails on curves should be double-spiked."

Then under the heading of "General," still under the heading, "Maintenance of Gage:

"1. The gage (tool) should be the standard gage."

There will be no change in Nos. 2, 3, 4, 5 and 6, with an additional paragraph, No. 7: "The use of gage rods is recommended on curves where it is difficult to maintain gage.

"Anti-Creepers.—The use of Anti-creepers to prevent longitudinal movement of rail in track is recommended."

On page 469, "Speeds of Trains Through Curves and Turnouts," that is eliminated as that is a matter, which has just been referred to, that was to be retained for further study.

"Index to Trackwork Plans." This text is to be omitted. This is the index shown in Trackwork Portfolio.

"Specifications for Frog Filler Sections. (That these specifications be omitted and that they be included in the Trackwork Portfolio)." Omitted from the Manual.

"Specifications for Relayer Rail for Various Uses." Under the heading of "Resawing Rails," omit. Omit the whole paragraph as the practice of resawing rails for use in main line is rapidly diminishing and on many roads has ceased entirely.

"Resawing and Reconditioning of Rails for Relaying, and Building up of Battered Rail Ends in Track." Omit the whole matter from the Manual.

Then it is recommended for inclusion in the Manual: "Building up of Rail Ends in Track. The reconditioning of rail ends, frogs, switches, crossings and joint bars is recommended as good practice."

Next is "Specifications for Malleable Iron Tie Plates." Omit the paragraph entirely as they are very little used now.

"Anti-Creepers." Omit the subject here. We have just above recommended a new heading and a new paragraph on this subject.

"Specifications for Steel Screw Track Spikes." Omit the text on pages 255 and 256, and designs on pages 257 and 258. At the present time these specifications are not used and the designs shown are not being manufactured. It is not desired to have anything in the Manual that is not currently alive.

"Oiling Track Fixtures.—The following is recommended as good practice:

"(1) Oil track bolts, joint bars and turnout fixtures.

"(2) Oil rail, tie plates and spikes when subjected to special corrosive conditions when ultimate life is affected.

"(3) Oiling of rail, tie plates and spikes to be done by machine; other materials by brush; new track bolts and joints to be oiled before applying.

"(4) Satisfactory oil for this purpose should conform to the following general specifications:

"Asphalt Base Diping Oil Specifications:

"Flash point, minimum, 130 degrees Fahr.; Asphalt, 100 penetration, minimum, 45 per cent; Viscosity, Saybolt Universal, 130 degrees Fahr., 240-350 seconds."

At the top of page 470, "Specifications for the Laying of New Track." Omit the text as now in the Manual and insert this reference: "Specifications for the Laying of New Track may be found in 1929 Manual, pp. 259 to 262."

It is not considered advisable that the new Manual should be encumbered with this but that a reference should be made to the matter as it now appears in the old Manual.

I move the adoption; with the understanding that the points referred to at various times will be considered by the Committee; the contradiction to which attention was called by Colonel Jenkins, will be eliminated and the chart which is upside down will be properly arranged.

First Vice-President A. R. Wilson:—You have heard the motion. Is there any discussion?

(The motion was put to vote and carried.)

Chairman C. J. Geyer:—I invite your attention to the Manual reference on the track tool plans, the second and third paragraphs on page 470. These plans have been redrawn, rearranged in numbering and some corrections made. The remaining three paragraphs have been changed to read for clarity as published in the Bulletin here.

The Committee recommends Index Plan A, page 21, be withdrawn and sheet entitled "Table of Contents," shown on page 478 of this Bulletin be substituted therefor; that Plans 1 to 22 inclusive, and Plan 25, shown on pages 27 to 39 inclusive be withdrawn, and Plans 1 to 22 inclusive, and Plan 25, March 1936, shown on pages 485 to 497 inclusive of this Bulletin be substituted therefor; that Track Tool Specifications shown on pages 22 to 27 inclusive be withdrawn and Specifications for Track Tools shown on pages 479 to 484 of this Bulletin be substituted therefor. I so move.

(The motion was put to vote and carried.)

Chairman C. J. Geyer:—The next subject, "Continuous Welding of Rail," is shown under Appendix B. This is an important development in trackwork and as it is new to this Association, the Committee went into considerable detail in preparing the report as information. The highlights of this report will be called to your attention by Mr. Fifield, Chairman of the Sub-Committee.

Mr. H. F. Fifield (Boston & Maine):—The assignment "Continuous Welding of Rail" is a new one. Due to the interest shown and the importance of the subject, the Committee has attempted to go into the matter as thoroughly as time permitted. An inspection of various stretches of continuous welded rail on the D. & H. has been made. The information obtained and the conclusions reached are presented herewith.

I move that the report be accepted as information and the subject continued.

First Vice-President A. R. Wilson:—I hear no objection. The Chair will so rule.

Chairman C. J. Geyer:—The next subject, "Plans and Specifications for Track Tools," is under Appendix C. The Committee recommends for adoption as recommended practice and printing in the Manual, Plan 12-A, dated 1935, AREA Carpenter's Adze. This plan was presented as information last year.

(The motion was put to vote and carried.)

Chairman C. J. Geyer:—The Committee also presents as information Plan 26, Scoop Shovel, and the Conversion Graph for Hardness Test, as shown on page 498 of this Bulletin.

First Vice-President A. R. Wilson:—This design of Scoop Shovel is presented as information and will be so considered.

Chairman C. J. Geyer:—The next subject, "Plans for Switches, Frogs, Crossings," etc., is under Appendix D. The report will be presented by Mr. Caruthers, Chairman of the Sub-Committee.

Mr. E. W. Caruthers (Pennsylvania):—The report of the Sub-Committee will be found in Bulletin 383. The subject which your Committee wishes to present this year is curved switches.

The necessity for high operating speeds makes the use of curved switches desirable in turnouts and crossovers. By their use the angle of impingement may be reduced materially, the radius of curvature throughout the turnout increased and in most cases the length of lead from point of switch to point of frog is decreased.

The use of curved switches will, therefore, provide greater safety and comfort, improved operating conditions for long rigid wheelbase locomotives, and economies in congested terminals where a shorter length of lead makes savings possible that could not be obtained with longer leads.

Plan 920 shows lengths, angles, and radii of curved switches; lengths and radii of leads and closure rails for turnouts of various frog angles from No. 5 to No. 20, both inclusive. This plan was prepared in conference with the Standardization Committee of the Manganese Track Society.

The Committee recommends that Plan 920 be adopted as recommended practice and published in the Manual, and I so move.

Mr. John V. Neubert (New York Central):—You have one word in there about your curved switches, "safety." I wonder if it would not be just as comfortable if you took the word "safety" out of there. In other words, one may think that a straight switch does not come in the category of safety.

Mr. E. W. Caruthers:—We will accept that, Mr. Neubert, gladly.

First Vice-President A. R. Wilson:—The motion is made that Plan 920 be adopted for curved switches.

(The motion was put to vote and carried.)

Chairman C. J. Geyer:—The Committee reports progress on the following subjects: Corrosion of rail and fastenings in tunnels, Appendix E; Practicability of using Reflex units for switch lamps and targets, under Appendix G; Reclamation of serviceable materials from scrap and retired maintenance of way and structures machines, tools and appliances, under Appendix H; Determination of the limiting relative positions of the abutting rails of fixed and drawspans of bridges and proper tolerances, under Appendix I.

First Vice-President A. R. Wilson:—As progress reports they will be received as such.

Chairman C. J. Geyer:—The next subject, Design of tie plates for RE rail sections as developed, is under Appendix F and the report will be presented by Mr. J. de N. Macomb, Chairman of the Sub-Committee.

Mr. J. de N. Macomb (Inland Steel Company):—The report of the Sub-Committee begins at the bottom of page 499.

During the current year, the Committee has continued its studies of this subject, and presents herewith Plans Nos. 1 to 6, inclusive.

These designs have the following characteristics:

Width, of all designs, 7¾ inches.

This width was selected as utilizing the available face of a nominal 8-inch tie.

Following that is a tabulation of the six plans, giving, respectively, their lengths, whether the ends are inclined or flat, the rail weights and sections with which the tie plate is to be used, and the eccentricity.

Plans Nos. 2, 3, 4 and 5 consist of two pairs of designs, two designs for use with 112-lb. RE rail and two for use with 121-lb. RE rail in each case, one design with flat ends for use with screw "Hold Down" spikes and one design with inclined ends for use with cut "Hold Down" spikes, or not to be separately attached to the tie.

Plan No. 1 is a 10½-inch section to be used instead of Plan No. 2, when traffic conditions do not justify the use of the larger tie plate.

Plan No. 6 is a 14-inch section to be used instead of Plan No. 5 when traffic conditions justify the use of a larger tie plate.

All designs have either double or single shoulder except Plan No. 6, which has double shoulder only.

All designs are canted approximately 1 to 40.

The designs with inclined ends provide for either rolled crown or pressed camber or no camber; those with flat ends have rolled crown only.

The bottom design is left optional with the purchaser, except that Plan No. 6 has flat bottom only.

The locations of spike holes are indicated, but other locations are optional with the purchaser.

Thicknesses are the minimum which will give satisfactory service when manufactured in "medium grade" steel in accordance with American Railway Engineering Association specifications. Increased thicknesses would be advantageous, but the Committee feels justified in presenting designs of minimum adequate thicknesses only.

In regard to presenting thinner designs of tie plates to be manufactured from higher strength steels, Dr. A. N. Talbot has advised the Committee that stiffness is important to obtain intensity of pressures at the ends of the plates that do not vary much from the average pressure on the tie . . .

"Although the deflections of the plate are small, the depression of the wood by the load on the plate is also small, of the order of 0.02 or 0.03-inch or less for a solid tie free from checks.

"For the same load and the same distribution over the plate, the deflection of the plate of Plan No. 2 is estimated to be nearly 50 per cent greater for a thickness of 21/32 inch than for 25/32 inch. This additional deflection interferes greatly with the desired distribution of pressure over the wood of the tie.

"It may be well to repeat that since the modulus of elasticity of two grades of steel is the same, the deflections of beams of the same thickness are equal when the loads and other conditions are the same, and also that changes of thickness apply equally to two grades of steel.

"The thickness of the plate and its resulting stiffness may govern even when the strength of the plate is otherwise adequate."

In view of the preceding, the Committee is recommending one series of designs only, which are suitable for manufacture in "Medium grade" steel.

The Committee recommends that Plans Nos. 1 to 6 inclusive be adopted as recommended practice and published in the Manual. I so move.

First Vice-President A. R. Wilson:—Gentlemen, the Committee have prepared and have submitted to us for adoption flat and inclined tie plates for the RE section of rail in the 112-lb. and 131-lb. weights. It has been moved and seconded that these plans be adopted and published in the Manual.

(The motion was put to vote and carried.)

Chairman C. J. Geyer:—That concludes the report of the Committee.

First Vice-President A. R. Wilson:—The Committee is excused with the thanks of the Association (Applause).

DISCUSSION ON COMPLETE ROADWAY AND TRACK STRUCTURE

(For Report, see page 69)

Mr. John V. Neubert (New York Central):—This report is found in Bulletin 381, on page 69, and is a progress report. We have received certain data in connection with our report this year. I suppose it is realized and appreciated that this Committee receives standards or recommended practices from the various Standing and Special Committees. It was felt by the Committee and as well by others, I am so advised, that on account of the active work going on in connection with revising the Manual we could do no better than go a little slowly, and next year it is hoped that we could have more material on which we could get together and give you something on this subject.

It is recommended that this subject be continued.

The President:—The subject will be continued and the Committee is excused with the thanks of the Convention.

The work of this Committee is essentially one of research—for which the foundation is being well laid for constructive action in the future. I believe the work of the Committee will be followed with increasing interest by Engineers generally. Ultimately this Committee will doubtless have an excellent opportunity to coordinate with the pioneer work being undertaken by the Special Committee on Stresses in Railroad Track (Applause).

DISCUSSION ON WOOD PRESERVATION

(For Report, see pp, 509–533)

Mr. C. F. Ford (Chicago, Rock Island & Pacific):—The report of Committee XVII —Wood Preservation, is shown on page 509, Bulletin 383. The subject, Revision of Manual, is shown as Appendix A, page 509. The Committee propose making a revision of the specifications for creosote and some deletions in the definitions of terms used in wood preservation. The report of this Sub-Committee will be presented by Mr. O. C. Steinmayer, Chairman.

Mr. O. C. Steinmayer (Canada Creosoting Company):—Under the heading "Specifications for Creosote," the Committee feels that it has been definitely determined that the float test requirement in the creosote specifications does not only fail in its original purpose, namely, that of detection of tar contamination, but occasionally discriminates against the known distillate oils. It does not serve as a measure of determining the quality of tar which may have been added to creosote in making the creosote coal-tar solution. It is for this reason your Committee recommends the withdrawal of the float test requirement in the Standard Specifications for Creosote and also in the Standard Specifications for Creosote Coal-Tar Solution.

Under the heading, Definitions of Terms Used in Wood Preservation, on page 510, your Committee feels, after reviewing the definitions of terms as now embodied in the Manual, that certain deletions as shown on page 510 can be made. There are certain changes made in the definitions without in any way voiding the matter as now appears in the Manual.

I move that the recommendations of the Committee be accepted.

The President:—You have heard the motion to accept the recommendations of the Committee for changes in the Manual.

(The motion was put to vote and carried.)

Chairman C. F. Ford:—The second subject assigned to the Committee is "Service Test Records for Treated Ties," and the report is on page 511 as Appendix B. The report is submitted as information.

Subject 3, "Piling Used for Marine Construction," is found in Appendix C, page 517. This is also a progress report submitted as information.

Subject 5, "Destruction by Termites and Possible Ways of Prevention," shown as Appendix D, is submitted as information.

Subject 6, "Effect on Preservative in Treated Ties in Track Due to Blowing Off Locomotives on Line of Road." The report of the Committee is found as Appendix E on page 530 and covers tests made on the Chesapeake & Ohio and Nickel Plate Railroads and is also submitted to you as information. That completes the report.

The President:—The Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON IRON AND STEEL STRUCTURES

(For Report, see pp, 265–271; 729–735)

Mr. G. A. Haggander (Chicago, Burlington & Quincy):—The report of this Committee is found in Bulletin 382, page 265, and in Bulletin 384, page 729.

Progress is reported on the following subjects:

(1) Revision of Manual: The Specifications for Steel Highway Bridges, and Rules for Rating Existing Bridges should be revised to be consistent with the revision of the Specifications for Steel Railway Bridges.

(2) Application of and specifications for fusion welding and gas cutting for steel structures.

(4) Design for Rivet Heads for Steel Structures.

(5) Stresses in Wire Ropes Bent Over Sheaves.

(6) Different Grades of Bronzes to be Used for Various Purposes in Connection with Iron and Steel Structures.

(7) Design of Expansion Joints Involving Iron and Steel Structures.

(8) Design of Tension Members and Connections in which Rivets Develop Tension.

(9) Effect of Proposed Increase in Vehicular Weights on Highway Bridges.

(10) Review specifications for overhead highway bridges of the Association of State Highway Officials in so far as they relate to steel construction.

Reports are presented for your consideration on the following subjects:

(1) Revision of Manual. The Rules for Rating Existing Bridges should be revised to be consistent with the revision of the Specifications for Steel Railway Bridges.

(3) Impact-Railway Bridges: Recommendations of this Sub-Committee are incorporated in the Rules for Rating Existing Bridges. A part of the work under this assignment was included in the Specifications for Steel Railway Bridges, adopted in 1935. The Committee is continuing its study of impact on ballasted deck steel bridges and short span steel bridges.

Revision of Manual, Appendix A, page 729, Bulletin 384. Your Committee recommends elimination from the Manual of the material under "Copper-bearing Steel for Structural Purposes," appearing in Supplement to the Manual, 1932, Bulletin 347, page 41.

Specifications for Steel Railway Bridges for Fixed Spans now has a provision for this material and the Manual material under "Copper-bearing Steel" is considered not necessary.

I move the adoption of this recommendation.

The President:—It is moved and seconded that the report as presented by the Chairman be adopted. Are there any questions?

Mr. A. C. Irwin (Portland Cement Association):—I think this Committee deserves the gratitude of all those of us who have been struggling with the question of impact for a great many years. The report as now presented approaches and attacks the subject in a logical order. The previous report, in the form it was adopted last year, lumped all of these various factors together and made it very difficult to discuss the subject.

The President:—The subject immediately before the Convention relates to copper-bearing steel and not impact.

Mr. A. C. Irwin:—I thought you were taking up discussion of "Rules for Rating Existing Iron and Steel Bridges."

Chairman G. A. Haggander:—We are asking that the material under Copper-bearing Steel for Structural Purposes be deleted from the Manual.

Mr. A. C. Irwin:—I beg your pardon. I wish to take a rain check on the opportunity to discuss this when you reach it.

Chairman G. A. Haggander:—At this time the Committee wishes to add a recommendation to its report.

Assignments 1 and 10 pertain to "Specifications for Steel Highway Bridges." Late in 1935 the American Association of State Highway Officials adopted a new specification for highway bridges. In this specification they included much of the work of Committee XV which appears in its Specification for Steel Railway Bridges which this Association adopted last year. The unit stresses, specifications for the materials, details of design, and so forth, are now consistent with our Specifications for Steel Railway Bridges. We believe that their new specifications is to be preferred to our 1929 edition. For this reason our specification was omitted when the "Blue Book" on Steel Railway Bridges and Concrete Railway Structures was published in 1935 and it is possible to save 53 pages of space now assigned to them in the new Manual.

We therefore recommend that the AREA specifications for Steel Highway Bridges, 1929, now printed in the Manual on pages 1180 to 1233 inclusive, be withdrawn from the Manual and recommend the use of the American Association of State Highway Officials Specifications for Steel Highway Bridges of 1935 pending further consideration of this subject by the Committee. I so move.

The President:—It is moved and seconded that the report of Committee XV—Iron and Steel Structures, as presented by Chairman Haggander, be adopted, the AASHO specifications to be used in lieu of the present specifications now appearing in the Manual.

(The motion was put to vote and carried.)

Chairman G. A. Haggander:—Your Committee recommends the elimination of the "Rules and Unit Stresses for Rating Existing Bridges," on pages 1248 to 1250 inclusive, of the current Manual, and substitution therefor of the following "Rules for Rating Existing Iron and Steel Bridges."

After it was too late to change the material under that heading in Bulletin 382, it seemed desirable to make certain changes, and the complete rules as revised now appear in Bulletin 384, page 729.

Minor changes were made in paragraphs 7, 8 and 12a. Paragraph 9 (c) was revised to make one of the formulas cover more general cases and to clarify the application of various formulas. It can be appreciated that the task of reducing the vast amount of material available on impact covering the many variations in spans, loading, speed, and so forth, is difficult, but it is the view of Committee XV that this is now in good, workable shape. A change was made in paragraph 15, "Permissible Stresses," penalizing

Bessemer steel and making the ultimate strength of the material a factor. These specifications differ from those in the Manual in several respects. Every force acting on a bridge is taken into account. The determination of impact is much more precise than in the present rules and can be obtained for any locomotive at any speed. The permissible stresses are a function of the yield point and ultimate strength instead of fixed values. Because of the fact that all forces are considered and because the impact is much closer to the actual than is the case in the present rules, the allowable unit stresses have been reduced.

Sub-Committee Chairman B. R. Leffler will now present the report.

Mr. B. R. Leffler (New York Central):—The report is found in detail on page 730 of Bulletin 384. Following the customary procedure, I believe it will not be necessary to read the details unless someone raises a particular question.

The first topic is a general statement on "Carrying Capacity."

The second topic is defined in a series of alphabetical paragraphs on "Inspection."

Next come details on instructions as to "Computation of Stresses."

Fourth, "Loads and Forces" are stated. As indicated by the Chairman, the intention has been to include in detail all forces acting on the structure.

"Dead Load" is defined.

"Live Load," under No. 6.

Then, "Impact." Impact takes two main divisions: First, a determination of impact for ordinary purposes, as given in paragraph 8.

Paragraph 9 gives the introduction to the "Precise Determination of Impact." This impact as quoted is divided into three major parts: Track joint effect, lurching effect, and hammer blow effect.

Following along, these respective effects are taken up in detail: (a) gives track joint effect, (b) gives lurching effect, (c) gives the hammer blow effect, with a number of formulas covering in detail how this hammer blow effect shall be computed.

In the middle of page 732 there is a note which defines clearly how these formulas shall be applied to existing bridges. I shall read it: "Note. This formula may be used to determine the permissible speed corresponding to a limited impact." That enables us to determine the permissible speed on existing bridges with the locomotive having a certain hammer blow.

Following that, the symbols in the various formulas are defined.

The next important detail is a statement on "Centrifugal Force", found in paragraph 10.

Paragraph 11 gives the wind forces in accordance with the corresponding requirements of the designing specifications.

No. 12 gives or states the requirements for a lateral force induced by a swaying locomotive.

No. 13 gives a statement of the lateral impact that shall be allowed due to the hammer blow effect and other effects on a superelevated track as found on curves.

No. 14 gives a statement of the longitudinal force requirements. In this respect, we have followed the requirements as given in the designing specifications.

No. 15 tells how to apply the live load and the respective impacts to multiple track bridges—a subject that has always been in an uncertain state.

Paragraph 16 gives in detail the methods of figuring the allowable unit stresses for overload.

As an editorial device, we have used certain symbols so as to avoid complication of language.

No. 17 is the final recommendation or the conclusions. I will read them:

"17. If the stresses exceed those permissible under these rules, the speed shall be so restricted, if practicable, that the permissible stresses will not be exceeded. If the speed cannot be so restricted, or if the design or the physical condition of the bridge makes it necessary, it shall be strengthened or renewed. When the permissible stresses are closely approached, or when the physical condition of the main members or the details are not good, the bridge shall be kept under close inspection as long as it is continued in service."

I overlooked an important note on No. 9: "For comprehensive discussion of Impact, see AREA Bulletin 380, and bibliography in Appendix C thereof."

That reference contains the foundation of all these seemingly terrifying looking formulas found in Impact. I said "seemingly," because they are not very difficult to apply when you understand the principle.

I move that these rules as amended and set forth in Bulletin 384, of which I have just given a brief outline, be adopted, as indicated by the Chairman, to replace corresponding matter in the present 1929 Manual.

The President:—It is moved and seconded that the recommendations of the Committee as presented be adopted for printing in the Manual.

Mr. A. C. Irwin:—I will not attempt to go over any of the previous ground, but "Track Joint Effect" is the first item in this report that is to be computed in determining the impact on a bridge.

At 100 miles per hour, this formula as proposed for adoption would produce 50 per cent impact from the wheel that hits the rail joint. The notation does not indicate whether or not that is to be the static wheel load or whether that is to include the effect of the hammer blow. I suggest a clarification of "W" under paragraph 9 (a), "Track Joint Effect."

Mr. B. R. Leffler:—The hammer blow is not a weight except as the excess counterweight is a weight, and the definition of *"W"* means the scale weight of the wheel. The real hammer blow effect is composed of velocity as well as of mass of the weight. It appears to the Chairman of the Sub-Committee that it cannot be misconstrued.

Mr. A. C. Irwin:—Is *"W"* the weight, the live weight of the wheel, axle, hub, pin, portions of siderods or connecting rods on the main driver, that is, unsprung weight, or is *"W"* here to be considered as the total static load, as, for instance, of an E-60 locomotive, in which case it would be 30,000 pounds? I ask: Is it 30,000 pounds, or is it 30,000 pounds plus the effect of hammer blow at the speed at which you are determining this factor *"S"*?

Mr. B. R. Leffler:—*"W"* here is intended to be the static wheel load.

Mr. A. C. Irwin:—"Static" wheel loads? I suggest the inclusion of that word.

Mr. R. B. Leffler:—If the Committee agrees, I have no particular objection to including the word "static."

The President:—Does the Committee agree? (Agreed). Consideration of the subject may then proceed.

Mr. A. C. Irwin:—I have nothing further to say. I am not offering a motion. I have had previous experience with attempts to amend this Committee's specifications.

Mr. B. R. Leffler:—We are beginning.

Mr. A. C. Irwin:—Does it mean 30,000 pounds for the E-60 locomotive? Is that *"W"*? If you are designing for an E-60 locomotive, is that 30,000 pounds?

Mr. B. R. Leffler:—I would say it is 30,000 pounds per wheel of E-60.

Mr. A. C. Irwin:—Static wheel load?

Mr. B. R. Leffler:—We define in No. 6 that "The live load shall be one of the Cooper's E series or else a load consisting of a specific locomotive or other equipment." It might be a car, one of these heavy gun cars without any excess counterweight.

Mr. A. C. Irwin:—I have a further remark on that. I understand that the rail joint effect specified here is more or less a theoretical one—that experimental data are largely lacking. If it is based on theoretical considerations, I submit that it is just as logical to apply the centrifugal force of an overbalanced locomotive driver to a rail joint as to a bridge for maximum moment or maximum sheer. That is, if you are basing this on theoretical considerations I suggest that it ought to include the overbalance effect.

Mr. B. R. Leffler:—When this locomotive running at a speed of 100 miles per hour, hits this rail joint, the locomotive is going to exert a certain amount of hammer blow, and this track joint effect formula does not say we are going to neglect the hammer blow; we are going to include it under hammer blow effect. Item (c) in paragraph 9. Whether the hammer blow occurs immediately at the track joint or ten feet away from the track joint does not make any difference. This requirement says it shall be taken as that produced by a concentrated load, acting on each rail at the center of the span. That is where a single concentrated load produces the maximum effect on any beam. So that will be added. The maximum amount of hammer blow effect at 100 miles per hour would occur on a short span of 25 or 30 feet. And there will also be the lurching effect, whether occurring at the rail joint or not.

The Chairman, Mr. Haggander, says the Committee will not object to the insertion of the word "static" between the words "maximum" and "wheel".

The President:—The Committee will accept the suggestion of Mr. Irwin, and the report will be corrected accordingly.

Mr. A. C. Irwin:—Now, as to the formula itself. There are three features or three conditions affecting rail joint impact. First, when the top of both rails is at the same elevation and with the same gap between the rails; second, when the receiving rail is lower than the other rail; and the third is when the receiving rail is higher.

In the first case, that is the top of rails in same elevation, we assume that they are held there by rigid joint bars or by some sort of bunching of ties or solid, well-tamped ballast. In that first case, the impact is affected by the time necessary to pass horizontally over the width of the gap at the joint. As the horizontal speed increases, this period becomes less and the drop is therefore less. From these considerations alone it would appear that the impact would be inversely as the speed instead of directly as the square of the speed. When the wheel hits the end of the receiving rail, it is given a vertical acceleration that is a measure of the amount of impact. Practically, very little of this impact can ever reach the main members of a bridge and it has a horizontal component.

Tests show that the vertical acceleration, that is, bounce of the wheel, is nearly proportional to the speed, not to the square of the speed as in this formula.

In the second case, that is, receiving rail lower, it is evident that there is a speed which is a comparatively low one, at which the wheel does not strike the end of the receiving rail at all. "Cupping," as distinguished from rail end batter, is the result. This "cupping" is much elongated on the rail head and this indicates that the wheel hones the rail head where it gains contact after dropping from the higher rail. It appears that in this case the vertical impact is not even directly proportional to the first power of the speed.

In the third case, that is, receiving rail higher, the high rail forms an obstruction that the wheel must pass over. The same general theoretical principles apply and the impact force may be shown mathematically to be directly proportional to the speed, not to the square of the speed, and inversely proportional to the square root of the wheel radius. The formula proposed is contrary to the theory governing this case, which produces maximum impact, both in that it involves direct proportionality with the square of the speed and neglects the diameter of the wheel.

If this formula is used for a short span bridge that derives most of its stress from the drivers of a locomotive, rail joint impact will amount to about 12 per cent if the hammer blow effect is neglected, and to nearly 20 per cent if the hammer blow effect is included. It is improbable that any such increase in stress occurs from rail joints.

If we were to accept the magnitude of impact as given by the formula, it is obvious that welding the rail joints to remove this impact effect would be imperative from an economical standpoint.

I am not suggesting a new formula, but certainly I hope that the Committee will have more time to get some factual and experimental data on this formula because when it is added to these other factors it certainly produces a condition that requires expensive designing.

The effect of lurching here proposed, namely, 20 per cent, seems also to be too high. Data obtained by the British Bridge Stress Committee do not justify this percentage. There are also some corollaries to this assumption that require consideration. Assume axial loads of 72,000-lb. Due to lurching this allowance would require that the load on one rail would be 57,600-lb. and 86,400-lb. on the other. The couple so formed by this difference in vertical forces must be balanced by a horizontal couple which will produce a 12,000-lb. thrust against the rail head. This thrust will be taken by one rail, and a computation of the stress in the web of the rail for one foot length of it produced by this horizontal force yields about 60,000-lb. per sq. in. in web of rail. This lateral force would also have to be taken into consideration in estimating the lateral loads on the bridge. This lateral force has evidently been neglected in this report.

The formula for hammer blow effect is unnecessarily difficult to apply. It involves a computation or measurement of the deflection of the span due to hammer blow of the locomotive at one r.p.s. Obviously it would be much simpler to compute the centrifugal force of the overbalance for the locomotive under consideration for spans whose period of vibration is so high that synchronous speeds cannot be attained.

Mr. B. R. Leffler:—As regards this rail joint effect, I think I am safe in saying that the Committee recognizes it as a field that should be covered by more experimental data, and that is what the Committee has asked in the way of funds. They have asked to have a Special Committee on Impact.

This WS^2 over 20,000 is not very much out of the way by any means. It is based on known sources and recommendations that I know our Committee knows oı, namely, the British tests. As to Mr. Irwin's discussion of the exponent of S, whether it is second power, first power, or a fractional power are questions on which keen minds, from time to time, do not agree.

The Committee took the view that WS^2 represents the stored energy in the moving wheel as a mass, according to the well-known mechanical principle that one-half times the mass times the velocity squared is a measure of rail joint impact. Even if we modify this by an empirical factor, which is 20,000 in this case, we have arrived at a practical result, and the experimental knowledge furnished by the British, and what little empirical knowledge we have, gave us results as precise as the present state of knowledge permits.

As to the lurching effect, I have known hopper cars that had 100 per cent lurch, the load being all off one rail and on the other. Locomotives do not act quite as badly as that. Based on the British viewpoint and experiments by Mr. Hunley given in Bulletin

380, the formula appears as a conservative statement of lurching impact or transfer of load from one rail to the other that may be expected in actual service of locomotives and trains.

I think Mr. Irwin's statement as regards the lateral force produced by this lurching is not in accordance with the recommendations of the Committee. In paragraph 12 we say, "The lateral force to provide for the effect of the sway of locomotives." Probably it would be more technically correct or more editorially correct to say "lurch of locomotives." Then it would read: "The lateral force to provide for the effect of the lurch of locomotives (in addition to the other lateral forces), shall be a moving concentrated load equal to one-sixteenth of the weight of one locomotive without tender, applied at the top of the rail in either lateral direction at any point of the span."

Knowledge of mechanics indicates that any vibratory body or pendulum is moved to one side or the other because a force acts on it. We recognize that in the ending of the clause as stated in No. 12.

As to the computation Mr. Irwin referred to, of the hammer blow effect, to state the effect in terms of simple formulas for centrifugal force would lead to far more complications, because we have here a combination not only of centrifugal force but centrifugal force with a synchronous condition. That is what these formulas mean. Simply stated, the formulas are a combination of the centrifugal force which I call hammer blow with the certain state of vibration of the bridge corresponding to the rotations of the driving wheel.

I do not believe the formulas can be simplified any more than as shown.

The Committee looks at it like this: If it is a question of taking a little time to determine the forces acting on an existing bridge or going at it in an easy sort of way and tearing out the bridge and spending thousands of dollars to save a little drafting room calculation, it looks like foolish and poor economy to hesitate at a little mathematical work that any skillful Assistant Engineer can perform in short order.

The President:—I gather from the remarks of the Sub-Committee Chairman, that he is not disposed to accept the suggestions for changes.

Mr. Theo. Doll (Santa Fe):—Like Mr. Irwin, I do not intend to make a motion, but should like to call attention to the fact that in the design of new girders the AREA specifications adopted last year require the designer to go to considerable trouble to compute the allowed spacing of stiffeners. This is required in order that the girder webs will not be made unnecessarily thick, and at the same time properly stiffened against buckling. Most of the older spans, for which these rating rules have been prepared, are sadly lacking in stiffeners all the way through; but especially near the ends, where the shear is high. The old Rules for Rating Existing Bridges (1929 Manual, page 1248) contained nothing about the spacing of stiffeners and, I am sorry to say, the proposed new rules contain nothing either. It would seem that the new rating rules ought to include a formula for the maximum spacing of stiffeners to be permitted without a reduction of the allowed unit shear, and a formula expressing the allowed unit shear as a function of the actual stiffener spacing.

Now, concerning the matter of impact, Mr. Leffler, in answering Mr. Irwin, stated that synchronism would be present. That is true, of course, for the longer spans, but for beam spans and girder spans it was admitted in the discussion last year (Proceedings, Vol. 36, pages 997 and 998), that synchronism is not a controlling factor, and that the hammer-blow effect is the important source of impact on such spans. Probably about 90 per cent of the tonnage of railway bridges is in beam and girder spans not more than 100 feet in length. For such spans it would seem that a simple formula involving the hammer blow, without synchronism, ought to be sufficiently exact.

Mr. B. R. Leffler:—First referring to Mr. Doll's statement about stiffeners, after everything is said and done, in regard to these old bridges you cannot cover in the rules precise statements regarding all kinds of details, and we have shown in sub-paragraph (b) of paragraph 3 something regarding web stiffeners. We say, "Spacing of web stiffeners, lacing and forked ends of compression members, eccentricity or riveted joints and connections, unequal stress in tension members, and secondary stresses" shall be considered.

Now it appears to me, and I think to the Committee, that, in this enumeration of the principal features that must be considered in weighing an old bridge or in considering it, we have covered everything fairly well without going into detail formulas and minute instructions as to how this work shall be carried out.

I remember a plate girder which is still in service, and every time a good train goes over it, the plate buckles. It has been there for about forty years. To look at it from somewhat a hysterical standpoint, we ought to pull out that girder; but we are not going to do so. I dare say that men who have had experience in inspecting bridges will find plenty of cases where the rules for design have not been carried out; either because they were not known at the time the design was made, or they were overlooked. In the art of considering old bridges, we have attempted to use fundamental principles, and have attempted to cover everything in these rules so far as possible and keep within the subject.

In regard to Mr. Doll's second point, I think Mr. Hunley, who has done a lot of experimenting with this synchronism, will agree that hammer blow effect occurs on spans as short as 30 feet, depending entirely upon the damping factors, whether the girder or beam is shallow or deep, and a few other empirical factors. For a short span of, say 30 or 40 feet, the synchronous effect probably would not occur until a driver rotation of 7 or 8 per second is reached; whereas, on a much longer span, say 50 or 60 or 70 feet, the corresponding effect at synchronous speed would come at about 5 revolutions per second. So we can not agree with Mr. Doll's statement that the hammer blow at maximum speed is what governs entirely. If it is possible to get synchronous speed on the span, the hammer blow at that synchronous speed is the major part of the impact.

Chairman G. A. Haggander:—I want to make a statement similar to the one I made last year. The criticisms so far, especially Mr. Irwin's, have been toward a reduction in what we propose in the way of impact. We admit now, as we did last year, that the knowledge on the subject of short span bridges and the track joint effect and the effect of ballasted deck is not complete, but we do not feel that we can justify reducing these allowances with our present knowledge. We have asked for an appropriation. Mr. Ford mentioned it in his address yesterday. Mr. Budd mentioned the matter of impact this noon. We must have further investigation but we do not feel that we can reduce these values with our present knowledge. We think and we know that we do have very valuable information on the open deck long span bridge. We want to keep the ground we have, not reduce impact values too much, but reduce them as we have definite knowledge.

With that statement, I should like to move the adoption of these rules for existing bridges.

Mr. C. C. Westfall (Illinois Central):—I do not want to discuss these rules because I have not had a chance to study them. I have too much regard for the membership of that Committee to talk about them without knowing what I am talking about, but I do think that the Committee rather owes it to the Association to give us a chance to study these rules and find out what it is all about before they ask us to adopt them.

Mr. Haggander says that the Committee admits the lack of knowledge of some features of impact. There are several things that I think should be ironed out. We had a committee formed after the specifications were adopted last year to study the proper live load, the Special Committee on Live Load and Impact. They are going further into the impact on ballast deck bridges. It seems to me these recommendations came out and were published in the February Bulletin. It may be that the Committee has analyzed some old bridges, but I think we should be given a year to study these things. Personally, I have no motion to make because this Committee carries a good deal of weight when a motion is made by the Committee. I would suggest that the Committee withdraw its motion and give this report as information and let the members have a chance to find out more about it before they are asked to vote on it. I doubt if there are very many on the floor and possibly many behind the table who can really vote on this thing intelligently.

Chairman G. A. Haggander:—Because of the lateness of this report we did discuss the very thing that Mr. Westfall has suggested. We discussed it very seriously to get the views of the members of the Committee. There was no objection on the part of any of them to adopting this, but we did discuss it, because we wanted to be sure of our ground. I thought a thing of this kind might arise. We have felt that the work was so valuable that we should not wait another year but that we should get the benefit now. I know in my own case personally we have had rated certain bridges by this method and it worked very nicely and we got results which are not at all out of line with the old method. It does give us better control of our speeds over old bridges. That is the main thing. The old specifications limited speeds to 15 miles an hour if the unit stresses using 50 per cent of the design impact exceeded the allowable. If the live load plus 50 per cent of the design impact exceeded the allowable we would limit the speed to 10 miles an hour providing that the live load plus 25 per cent of the design impact did not produce stresses in excess of the allowable. That is quite a handicap. Under these specifications we bring that speed up. That is the main difference in the actual working out of the thing. We rated spans in our own office from 40 to 150 feet in accordance with the proposed rules. The track joint effect which Mr. Irwin mentions is about 2 per cent of the total effect, total bending moment, on a 50-foot span and less than 1 per cent on an 80-foot span. It is quite negligible for spans over that length. It has more effect on short spans, of course. We did consider this question of holding it over another year. Most of us felt we wanted to use it right away.

Mr. C. C. Westfall:—You can use it as information. It is information available. We can all use it and next year we can talk about it, and know what we are talking about.

Chairman G. A. Haggander:—We discussed the matter and thought we would leave it to the wishes of the Association as to whether it should be adopted or held over.

Mr. S. L. Wonson (Missouri Pacific):—The Committee is to be complimented upon this report on a very important subject that involves highly controversial matters. The convention is not in position to discuss these technical matters but the remarks of the first commentator indicated a feature that should be given consideration. These formulas are familiar to the Committee. The Committee has worked on them and knows just what they mean. Another competent critic with adequate technical background does not know what the formulas mean. The formulas should be placed in air-tight form so that they will be perfectly clear as to fundamentals.

Paragraph 8 speaks of the ordinary calculations of impact. The Sub-Committee Chairman has said, in effect, that in the ordinary case the impact will be calculated by the AREA specifications quite correctly.

Chairman G. A. Haggander:—Yes.

Mr. S. L. Wonson:—And that a more precise determination of impact may be made in another way.

I think it would be helpful if the Committee would tell us what is the ordinary case and what cases are not ordinary, and under what conditions and circumstances we should use the more precise calculations, and what in general is the zone of variation between the two methods. That is one of the fundamental backgrounds of an alternative or double method of calculation.

Chairman G. A. Haggander:—We will let Mr. Hunley reply to that. He made a study on this thing.

Mr. J. B. Hunley (Big Four):—Answering Mr. Wonson's question as to the ordinary method, or what we called the ordinary method of determining the amount of impact. Frequently we are asked as to handling foreign equipment of which we do not know the counterbalance of that locomotive. You can give a quick answer by this design formula which is referred to under paragraph 8. Also, if you are rating another span and it passes, you may be sure that it will take any engine safely, so far as the amount of impact is concerned. In the last month we have rated about 15 girder spans, running from 30 feet to 80 feet in length, by this new method. It also happened that these spans were all built under one specification, that of 1893. Under the old impact formula, that of two years ago, they required speed restrictions. They were Bessemer steel and the permissible stress under these rules is 21,000 pounds. If we rated them with the design formula referred to in paragraph 8, the locomotive impact on a span of 30 feet was about 73 per cent. With our heaviest counterbalanced locomotive in service, with this proposed precise method, the impact amounted to about 53 per cent. The static stress was about 12,000 pounds. With the difference of 20 per cent in impact, the decrease in stress was about 2500 pounds. The ordinary method referred to under No. 8 actually threw those bridges out. It gave us a stress of about 24,000 pounds. This precise method brought them down to 21,000 pounds. That is just the difference. If you do not want to bother with this precise method, do not use it. But when it comes to a question of putting on speed restrictions, which are always expensive, or of renewing the bridge, which is equally or more expensive, it pays to spend an hour or two to compute them by the precise method. It is well worth while and it is not at all difficult to apply.

Mr. S. L. Wonson:—The precise method gives a quite wide variation in results from the ordinary method, up to 50 per cent?

Mr. J. B. Hunley:—Simply because the ordinary method will cover anything.

Mr. S. L. Wonson:—What are the variations in results?

Mr. J. B. Hunley:—It depends upon what locomotive you use.

Mr. S. L. Wonson:—In the general situation?

Mr. J. B. Hunley:—On the long spans the difference ran about 10 per cent; on the short spans about 20 per cent.

Mr. S. L. Wonson:—You cited a case where you had a variation of about 50 per cent between the two methods.

Mr. J. B. Hunley:—On locomotive impact alone.

The President:—While the Chair has no desire to shut off this interesting and annually recurring debate, I wish to point out that there is a motion before the convention that the report be accepted. May I say in this connection that the Committee recognizes that there are, and will remain, controversial matters connected with this problem until funds and facilities are made available for that character of factual study which is necessary before satisfactory conclusions can be reached. The matter to be decided is, will the convention take the most reliable data that the Committee is able to develop at this time for publication in the Manual or does the convention believe that the subject should be referred back to the Committee and leave nothing on the subject in the Manual for still another year?

The pending motion is, does the convention favor accepting the Committee report as the best guide for this Association until something better can be reported and accepted. Are you ready for the question?

Chairman G. A. Haggander:—We offer this for adoption and inclusion in the Manual to replace the present material in the Manual.

Mr. B. R. Leffler:—And because the present material is so inferior, we are offering you something better than you have.

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western):—Strange as it may appear, I will not discuss the impact formula as my position was pretty well stated in the last convention. I still feel that, in the light of the fact that it is conceded that undoubtedly impact effects on solid floor bridges and reinforced concrete structures are greatly reduced, a footnote should at least be added to the present impact formulae stating that for solid floor bridges these impact increments are known to be too high, but sufficient data has not been gathered to justify actual allowances for such conditions. My question pertains to the conclusions on page 735, the second sentence of which reads, "If the speed cannot be so restricted," etc. I want to know this: Supposing you are in a place on the line where the speed cannot be restricted. You analyze your bridge and your bridge cannot stand the stress that you find. What are you going to do?

Chairman G. A. Haggander:—Replace it.

Mr. Meyer Hirschthal:—Until the time you replace it?

Chairman G. A. Haggander:—If you find the proposed engine cannot operate over that within these rules, you must take it out.

Mr. Meyer Hirschthal:—You cannot take it out the day after, can you?

Chairman G. A. Haggander:—These engines are presumed to be referred to you before they are operated. It is not presumed that they are going to take a very heavy or a larger engine than you are operating without permission of the Bridge Engineer.

Mr. Meyer Hirschthal:—That is the question I raise. Suppose your bridge inspector comes in with a report on a bridge. He has inspected it and finds that the members are deficient in strength to carry the main line locomotives, not the new locomotives. The stresses are exceeded. Even in a place where you cannot restrict your speed, you still have to do something about it. The only thing you can do is restrict the speed. According to this conclusion that is what you would not do.

Chairman G. A. Haggander:—You either have to restrict the speed or put on falsework until you can replace, one of the two.

Mr. G. E. Robinson (Big Four):—There are a couple of editorial corrections here that I think should be made Under paragraph 9 (b) "Lurching Effect," it reads: "It shall be taken as 20 per cent of the static live load." I think that the words, "on one rail" should be added right there. I am afraid that as it stands somebody would take 20 per cent of the total static live load, which is not correct.

Also, under the heading of "Longitudinal Force," the Committee puts this force entirely in terms of percentage and they do not state on what lengths of bridge. The ordinary thinking designer when he is talking about longitudinal force is thinking of the length of track between expansion joints, and as I understand the Committee's position they intend this 15 per cent to apply to just the spans over the column. I think that should be clarified.

I make a motion, in the first case, that the words "on one rail" be added after "static live load."

Mr. C. C. Westfall (Illinois Central):—This goes to the question now before the house.

The idea of the motion, as I understand it, is to delete the present material on rating existing bridges printed in the Manual and substitute this, merely putting this in because there would be nothing in the Manual otherwise. It seems to me that the Manual should not be considered as a year book. But that it is published and not touched for six or eight or ten years. It is right now due to be rewritten. Lots of the material in it is obsolete. It seems to me that it would be proper to take out the existing material and still hold this over. The Manual is not going to be published yet, but we cannot be revising the Manual every year. The Committee has indicated that they wanted to continue this subject. If the Committee will come before us and say, "We are done with the subject," then the best thing to do is to put this in the Manual. But if they say they want to continue it, I do not think it is ready to put in the Manual.

The President:—For the information of the last speaker, the new Manual will be in looseleaf form and so arranged that obsolete material may be removed and new or additional material added without difficulty. Provision has also been made whereby our Manual can be corrected currently.

Chairman G. A. Haggander:—I will say further in regard to this material which we think requires further study, the question of impact on short span bridges and rail joints, ballast decks, and so on, we figure that it will take two or three years before anything definite or better than what we have can be secured. We could not possibly do it in a year. It would be a matter of two or three years or maybe longer.

Mr. Theo. Doll:—I want to second Mr. Robinson's motion, although it is probably a waste of breath.

The President:—Mr. Robinson, will you please restate your motion.

Mr. G. E. Robinson:—I suggested the inclusion of the words "on one rail" after the words "live load."

Chairman G. A. Haggander:—I will say that is an editorial change to clarify the meaning and we will take it under advisement and change it so as to be absolutely clear. We know what you have in mind.

The President:—Is that satisfactory?

Mr. Theo. Doll:—Yes, sir. I move the previous question.

The President:—The previous question is moved. All those in favor of accepting the report of the Committee as presented will signify by saying "aye"; contrary-minded, "no." The motion is carried.

Chairman G. A. Haggander:—That concludes our report (Applause).

The President:—Mr. Haggander, I know something of the difficulties with which you and your Committee have had to contend during the past year, principally from lack of facilities and funds to extend the lines of engineering or experimental research which has become so necessary in your studies. It is largely for the reason also that I have a great deal of sympathy with the inquiries which have been made from the floor. Your Committee and you personally, Mr. Chairman, have done splendid work, and the Association is to be congratulated on the ability of this fine Committee of Engineers.

You and your Committee are now excused with the thanks of the Association (Applause).

DISCUSSION ON LIVE LOAD AND IMPACT

(For Report, see pp. 273–274)

Mr. O. F. Dalstrom (Chicago & Northwestern):—The report of the Committee on Live Load and Impact will be found in Bulletin 382, on page 273. This a new committee. It was organized in October 1935 and the assignment was to study and recommend a live load which could be used for all AREA specifications for the design of structures. In addition to that, the study of impact was to be carried forward either under new assignment or from the point to which it had progressed.

The Committee's first undertaking was to study the record of live load to see what had been done and what was available in the form of records. The records of the three Committees on Iron and Steel Structures, on Masonry, and on Wooden Bridges and Trestles, were investigated, and it was found that the Committee on Iron and Steel Structures had made about the only records of scientific studies that were available. Those studies extended back about twelve years. On the basis of those studies, which were made available to this Committee, the Committee submits what is now given in Appendix A in this report under "Live Load."

I move the adoption of "Live Load" as shown in Appendix A in this report.

The President:—Is there any question?

(The motion was put to vote and carried.)

Chairman O. F. Dalstrom:—Under Appendix B, we treat the subject of Impact. Due to the fact that this Committee was not organized until about six months ago, no effort was made to start this work on impact, but for the information of the Association we have submitted a brief which I will read in full. It will take only a few minutes.

"While your Committee is not prepared to submit any recommendations on impact for your consideration at this time, your attention is invited to the record of tests and discussion of 'Impact in Steel Railway Bridges of Simple Span,' in AREA Bulletin 380, October, 1935, by J. B. Hunley, a member of this Committee.

"In the Foreword to this discussion is given a brief review of the pioneer work in this field by Prof. F. E. Turneaure, Dean of the College of Engineering, University of Wisconsin, the results of which were published in the AREA Proceedings of 1911. Following this review of Dean Turneaure's work is given a summary of the research work carried out in foreign countries. The author then presents the report of his tests on steel bridges of the C.C.C.&St.L. Railroad during the years 1931 to 1934 inclusive. This report is based on about 2100 test records on 39 bridges, all simple spans and most of them open-deck bridges. This is the most comprehensive report that has been made on the subject of impact. While it served the immediate purpose that the C.C.C.&St.L. Railroad had in view and was the basis of the present AREA impact formula for steel railway bridges, it also indicates the need of extending this research to cover spans of lengths and types different from those tested, particularly short spans, steel spans with decks carrying ballasted tracks, continuous or rigid frame structures, and concrete bridges of all types."

The President:—This report is being submitted as information and it will be so received. The Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON ECONOMICS OF BRIDGES AND TRESTLES

(For Report, see page 99)

Mr. Arthur Ridgway (Denver & Rio Grande Western):—The report of the Special Committee on Economics of Bridges and Trestles will be found on page 99 of Bulletin 381. It is a progress report and we have nothing to add.

The President:—This is a progress report and is received as information; no action is necessary. The Committee is excused with the thanks of the convention (Applause).

DISCUSSION ON WOOD BRIDGES AND TRESTLES

(For Report, see pp. 665–721)

Mr. H. Austill (Mobile & Ohio):—The report of your Committee on Wood Bridges and Trestles appears on page 665, Bulletin 384. In the absence of Mr. D. W. Smith, Chairman of the Sub-Committee on Revision of Manual, I will present that subject.

You will note, beginning on page 666, the usual form of presenting revisions of the Manual has not been followed. That is to save printing. In view of that, I will run through the proposed changes by page, pausing sufficiently to give you time to discuss any particular change.

Page 666 of the Bulletin: Changes are proposed on pages 449, 450, 456, 458, 459, 462, 467, 468 and 469 of the 1929 Manual.

I will say here that the Committee last year presented to you a specification for piling to be used in highway bridges. This specification combines that specification with material now in the Manual, with some minor changes, the principal change being measurement of the butt diameter 3 feet from the butt instead of 6 feet, as now in the Manual. In doing that, the diameter dimensions shown 3 feet from the butt, the minimum diameter on oak, cypress and chestnut, the Committee has decided should be 14 inches instead of 12, as shown on page 669 of the Bulletin.

A change is made on page 472 of the Manual; changes on page 473 of the Manual. Changes proposed for page 474 of the Manual, this being an addition of the botanical names of hardwoods to the botanical names of softwoods now in the Manual, since specifications to be presented include specifications for hardwoods.

Changes are proposed on pages 474, 488, and 494 to 497 of the Manual.

I will say here that this covers "Specifications for Wood Shingles." There are some differences of opinion as to whether this is proper material for this Committee, and this is presented with the understanding that the Committee on Manual will place it where they deem proper in the Manual if adopted.

A change is proposed for pages 552 to 557 of the Manual; a change is proposed for pages 558 to 560 of the Manual.

I move the revisions of the Manual covered on pages 666 to 682 inclusive of Bulletin 384, with the exception of the change in dimension, the diameter 3 feet from butt of first-class oak, cypress and chestnut piles for railway bridges, which is to be made 14 inches instead of 12 inches, as shown on page 669, and with the understanding that a few minor corrections and typographical errors be made before editing, be adopted.

The President:—It is moved and seconded that the report of the Committee be accepted and adopted for printing in the Manual.

Dr. Hermann von Schrenk (Consulting Timber Engineer):—I do not like to see this specification for wood piles go by without expressing a word of commendation. I think this is the first time we have had 100 per cent agreement on the part of the three great engineering bodies of the United States—the American Society for Testing Materials, the American Railway Engineering Association, and the American Association of State Highway Officials. Nowadays when we are dealing with the problem of grade crossing elimination a standard piling specification is a very important subject. I think this Association is to be congratulated on taking this step and in making this recommendation for a uniform standard.

(The question was put to vote and carried.)

Chairman H. Austill:—Subject No. 2 will be presented by Mr. W. E. Hawley, Chairman of the Sub-Committee.

Mr. W. E. Hawley (Duluth, Missabe & Northern):—The report on "Simplification of Grading Rules and Classification of Timber for Railway Uses," is found in Bulletin 384, pages beginning 683, Appendix B, and is devoted to a new specification for structural timbers of both softwoods and hardwoods. The report has been prepared as substitute material for older specifications now in the 1929 Manual. The general purpose of the new specifications is to enable the user to easily assign working stress values to timber containing defects not greater in extent than those sizes shown in the tables of this report and to enable the producers to so grade their product as to meet this purpose.

The Committee at a meeting held yesterday made some changes in the form as printed in this Bulletin now before you and these I shall briefly note. On pages 685 and 686, Sections 7 to 18 under the side title "Close Grain and Density," are to be left out, and material in Section 14 on "Density," and 15 on "Close Grain" of last year's report, pages 787 and 788 of Bulletin 374, excluding mentioning of "larch" and substituting the descriptive term "pith pieces" for the term "boxed heart" where used in the old report, are to be substituted therefor, with the sections in this material and following in this year's report to be renumbered properly. The purpose of this change is to make it easier for users to copy material relating to one or the other species of wood when selected for close grain or density.

On pages 690 to 699 inclusive the Committee will rewrite the tables for defects in terms of fractions of an inch in sixteenths or multiples thereof, instead of the odd fractions 1/5 or 1/7.

The Committee has noted errors of editorial character, punctuation and mechanical make-up which will be corrected in the printing and we do not think it necessary to burden the meeting with these details.

I therefore move that this material on page 683, beginning with the title, "Grading Structural Timbers on the Basis of Unit Working Stresses—1936," through to page 703 inclusive, with the changes as made, be adopted by the Association for printing in the Manual. This motion includes the withdrawal of all material now in the Manual in conflict therewith, that is, pages 505 to 551, and pages 558 to 560, to the end of material on "Structural Oak."

The President:—It is moved and seconded that the report as presented by the Committee and modified by the changes recommended be now accepted and adopted for printing in the Manual.

(The motion was put to vote and carried.)

Chairman H. Austill:—Mr. R. P. Hart, Chairman of the Sub-Committee on Assignment No. 3, "Overhead Wood or Combination Wood and Metal Highway Bridges," is not here. I will, therefore, present his report, which occurs on page 704. This report is brief and merely presents for adoption in the Manual the plan for overhead highway bridges.

I move that this plan appearing opposite page 704 be adopted for printing in the Manual.

The President:—It is moved and seconded that the report of the Committee be accepted and adopted for printing in the Manual.

(The motion was put to vote and carried.)

Chairman H. Austill:—Subject 4 will be presented by Mr. H. M. Church, Chairman of the Sub-Committee.

Mr. H. M. Church (Chesapeake & Ohio):—Appendix D, Design of Wood Trestles for Heavy Loading, is found on page 704. This design was presented last year, and for open deck trestles, for walkways and platforms, and consideration has been given to comments received during the year. The main body of the report outlines what those comments were and I will not read them in detail. A proposed design is shown of a ballasted deck trestle. Therefore, I will just refer to the conclusions, page 705.

"It is recommended that the design of open deck trestle for E-72 loading submitted with this report, together with the table of stresses, be adopted for inclusion in the Manual as recommended practice, and I so move

(The motion was put to vote and carried.)

Mr. H. M. Church:—A design for walks and platforms is submitted and I move that it be adopted for inclusion in the Manual.

(The motion was put to vote and carried.)

Mr. H. M. Church:—The proposed plan and table of stresses for ballasted deck trestle is submitted as information and it is the hope of this Committee that they will have the benefit of comment and criticism during the current year.

The President:—It will be so received.

Chairman H. Austill:—On Subject No. 5, progress is reported. I call your attention to the fact that mimeographed copies of the bibliography referred to are on hand for distribution. If anyone wants them he can get them from Mr. Oliver.

Subject No. 6 will be presented by Mr. W. R. Wilson, Chairman of the Sub-Committee.

Mr. W. R. Wilson (Santa Fe):—The report of this Sub-Committee appears in Appendix F, pages 706 to 716 inclusive of Bulletin 384. Attention is called to a typographical error in the third line of the second paragraph, on page 706 where it says "per blow, at each pull stroke." The word "pull" should be "full."

The Committee has been working on the assignment from two phases, namely, the practical and the theoretical. In the first phase, we have endeavored to find out how the various agencies actively engaged in driving piles choose the hammers they use, and to this end we are presenting the conclusions of several such agencies. In the second phase, that is, the theoretical, Exhibit A is presented with the hope that it will invite comment and criticism. This discussion offers an interesting approach to a theoretical method of determining the relationship between the energy of the hammer and the weight of the pile. Your Committee is in receipt of a letter from the Bureau of Yards and Docks of the United States Navy Department, commenting on this report. I will quote from this letter: "As far as the Bureau's records indicate, on page 709, Formula 4 was not actually used by the Bureau. It was suggested by Captain McKay as a possibility, but he preferred the Eytelwein formula, as indicated at the bottom of page 710. Although the Bureau has used the Eytelwein formula in recent years the Bureau has preferred Formula 2 on page 709." (This is the Engineering News formula.) "A comparison of penetrations per blow required by Formula 2 with those obtained from the Eytelwein formula indicates that for some conditions of pile and hammer weights the latter (Eytelwein formula) gives larger penetration per blow for the same theoretical bearing power. The Bureau has therefore preferred to use Fomula 2" (which is the Engineering News formula) "unless, in any particular case, a formula which includes the relative weights of pile and hammer requires smaller penetration for the same load."

Your Committee is cooperating with the Committee on Pile Driving Formulas and Tests of the Waterways Division of the American Society of Civil Engineers, and there has been a free interchange of information between the two committees. This report is submitted as progress with the recommendation that the subject be continued.

The President:—It will be so accepted.

The Convention will be interested to know that the Board of Direction has approved the designation of Mr. W. R. Wilson, of the Santa Fe, to represent this Association at the Harvard University Conference on Soil Mechanics, June 22–26.

Chairman H. Austill:—On Assignment 7 the Committee presents no report.

The report on Assignment 8 is to be presented by Mr. G. M. Cornell, Chairman of that Sub-Committee.

Mr. G. M. Cornell (Chesapeake & Ohio):—The report of this Committee is shown on pages 717 to 721 of Bulletin 384. The first part of this assignment deals with the ordinary classification on railroads of O.G. washers, separators, and so forth, and the recommendation in connection with them is shown on page 720.

The first recommendation is that the present specifications in the Manual covering the design and specification of cast or malleable washers and separators be continued and that no changes or additions thereto be made at the present time.

During the past several years considerable work has been done in connection with timber connectors for wood framed structures. The Sub-Committee took this up as a special subject this year and the balance of the report covers this one item.

Since the report was made, some changes have come to the attention of the Committee, but as they are all quantitative rather than qualitative, I will not bother to present them in detail. They will be presented in the Proceedings and published. However, I would like to call your attention to the table at the bottom of page 719, which contains the gist of this report. In the last column please substitute the 4-in. split ring with a value of 5100 lb., and a 4-in. toothed ring with a value of 2300 lb., which changes will appear in the revised report. From this table you will see that for the 3″ × 10″ brace 20.5 feet long, which would be the longest brace, a diagonal brace in the longitudinal bracing system, the value in compression of the brace is 1950 lb., and the value of one bolt 1-in. diameter is 1090 lb. In other words, one bolt is only about half as good as the piece of timber. When we come to the 6″ × 10″ longitudinal strut, the value in compression is 29,000 lb. and the value of the 1-in. bolt is only 1090 lb. In other words, the timber is good for 26 times as much as the fastening.

With the use of connectors, while we cannot fully develop the strength of timber except in the longer members, we can considerably raise the value of the connection. However, we have not as yet found a suitable connection to use between a flat brace and a round pile. This is something which the Committee expects to take up and give further study. All of this is presented as information.

The President:—It will be so received.

Chairman H. Austill:—On Assignment 9, the Committee reports progress.

That completes the report of your Committee.

The President:—Colonel Austill, your Committee has done some splendid work. The revisions of the Manual that you have presented represent an enormous amount of labor and I am reliably informed that you have done your work well. You are excused with the thanks of the convention.

Chairman H. Austill:—Permit me to say, please, that my associates did the work, and they did a good job. Thank you.

The President:—That shows you are a good Chairman (Applause).

DISCUSSION ON MASONRY

(For Report, see pp. 631–654)

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western):—The Masonry Committee this year presents a report as printed in Bulletin 384, pages 631 to 654 inclusive. The subjects reported on are seven in number, of which three are presented for inclusion in the Manual.

The first subject is Revision of Manual, Appendix A. Due to the brevity of this report, Mr. Leonard, Chairman of the Sub-Committee, has asked me to present it.

The revision consists first of Article 10 of Section I, where the specifications are brought up to date to conform to serial designations of the ASTM specifications.

I move the acceptance of this part of the revision of the Manual.

(The motion was regularly seconded, put to vote and carried.)

Chairman M. Hirschthal:—The second revision is that of Article 22 of Section II, Proportioning and Mixing, the same type of revision, bringing the specifications up to date with the serial designations of the ASTM specifications. I move adoption of that section.

(The motion was regularly seconded, was put to vote and carried.)

Next is also a revision of Specifications for Billet Steel Concrete Reinforcement Bars, to bring those up to date to conform to serial designations of ASTM specifications. I move its adoption.

(The motion was regularly seconded, was put to vote and carried.)

Chairman M. Hirschthal:—The next subject is that of Specifications for Reinforced Concrete Culvert Pipe, which have been recently revised by the American Society for Testing Materials in a committee that had representation from the AREA. There has been presented to the ASTM a tentative specification for Reinforced Concrete Culvert Pipe. I therefore move the deletion of the material at present in the Manual and the substitution of a reference to the present serial designation of specification of the ASTM pending its adoption. I so move.

(The motion was regularly seconded, was put to vote and carried.)

Chairman M. Hirschthal:—The next section is that on revision of Article 4 of Section I. There is a typographical error there. At the end of the line it should read "Test for Organic Impurities in Sand" instead of "Original Impurities."

I move the adoption of this article as a revision of the Manual.

(The motion was regularly seconded, was put to vote and carried.)

Chairman M. Hirschthal:—The last subject for revision of the Manual is that of Article 13, page 568, in which there is also a typographical error. The serial designation should be A-82-34, which is simply a coordination with that of the ASTM's most recent specification. I move adoption of this Article.

(The motion was regularly seconded, was put to vote and carried.)

Chairman M. Hirschthal:—The next subject presented by the Masonry Committee is that contained in Appendix B, Assignment No. 2, Specifications and Principles of Design of Plain and Reinforced Concrete.

Mr. A. N. Laird, Chairman of the Sub-Committee, is unable to be present and has asked me to present the report for him.

This report consists of two sections, the first of which is plans in detail for reinforced concrete railroad trestles with three pile bents, designed for Cooper's E-72 loading, and 24-inch precast reinforced concrete piles. The details of both the stresses, the slabs and the concrete pile, as well as bending moments for handling and the table for quantities and so forth, are contained in the insert. I move the adoption of this for inclusion in the Manual as recommended practice.

(The motion was regularly seconded, was put to vote and carried.)

Chairman M. Hirschthal:—The next section is that referring to Wind Load Stresses —Composite and Pipe Columns. The first sub-division, "Unit Stresses for Buildings when Wind Loads are Included," gives a provision for allowing an increase of 33 1/3 per cent in allowable stresses, and this paragraph is presented for your consideration as information.

The President:—It will be so accepted.

Chairman M. Hirschthal:—The next sub-division of this section is "Specifications for Composite Columns and Pipe Columns." This fills a void in the present Manual and present specifications which has been felt for a long time and which the Committee on Buildings has long been asking the Masonry Committee to supply. This is now presented for study during the current year and suggestions, comments and criticisms or any corrections that may be found necessary in these specifications. I present it as information.

The President:—It will be so received.

Chairman M. Hirschthal:—The third section is that on the Design of Rigid-Frame Bridges. The Committee this year presents specifications and "Recommendations for the Design in Reinforced Concrete of Rigid-Frame Bridges Without Skew." This is also presented as information with the request for criticisms and suggestions for changes or additions from the membership. There are, however, several corrections on account of typographical errors to which I should like to call your attention since they are very short. The first occurs on page 636, about the third of the page down, in the formula for end moments. In that formula, in the first member, the "1" above the line should be *"I"*.

The next correction is in that paragraph starting with "Fixed-end moment," page 636, just about a third of the way farther down. "Fixed-end moment due to unit concentrated load." The error consists in the omission after the second part of this formula of the symbol *"x."*

The third typographical error occurs on page 637 at the bottom of the page under "Effect of Distortions." The formula shown there for $M_1 = E$ etc. should be E times $(Y_1—x_1)$ instead of Xy and the denominator should consist of two terms $\Sigma y^2 \frac{\Delta}{I}$ minus the rest of the term. With these corrections this material is presented as information.

The President:—It will be so received.

Chairman M. Hirschthal:—The third subject presented in the report of the Masonry Committee is that contained in Appendix C, "Progress in the Science and Art of Concrete Manufacture—1935." Mr. L. W. Walter, Chairman of this Sub-Committee, will present this report.

Mr. L. W. Walter (Erie):—The report of the Sub-Committee is presented as Appendix C in Bulletin 384, beginning on page 640. It consists of two sections. In Section 1 is presented proposed "Specifications for Curing Portland Cement Concrete." Two changes are requested in the report as printed. Please refer to paragraph 3 under "General," on page 640 and change the word "one-third" to read "40 per cent."

For the other change, please refer to page 641, paragraph 3, line 3, and change "52 hours" to read "67 hours."

With these changes, your Committee recommends the adoption of these specifications for inclusion in the Manual. I so move.

(The motion was put to vote and carried.)

Mr. L. W. Walter:—The next section of this report deals with "Grouting and its Application to Masonry," and it is presented as information only. I move that it be received as such.

The President:—It will be so received.

Chairman M. Hirschthal:—The fourth assignment of the Masonry Committee is Contact with Joint Committee on Standard Specifications for Concrete and Reinforced Concrete." The Committee reports progress on this contact work and expresses the hope that by the end of the summer of this year all the material of this Joint Committee will be in publication form and ready to be presented for criticism to the various associations involved.

Subject No. 5 is "Specifications for Foundations," contained in Appendix D. In the absence of Mr. Rush, I am compelled to present the report.

These specifications for foundations appearing as specifications for substructures were presented as information last year with the invitation to the convention to criticize them for the purpose of revision or correction. This subject is now presented for inclusion in the Manual as recommended practice and I so move.

(The motion was regularly seconded, was put to vote and carried.)

Chairman M. Hirschthal:—The next subject is contained in Appendix E and is "Methods and Practices of Lining and Relining Tunnels." The report will be presented by Mr. G. F. Eberly, Chairman of the Sub-Committee.

Mr. G. F. Eberly (Baltimore & Ohio):—This Sub-Committee has to present to you this year "Specifications for Lining Railway Tunnels with Plain Concrete," which will be found in Bulletin 384, pages 645 to 648 inclusive.

Before presenting these for adoption in the Manual, I should like to call your attention to a few changes that we agreed to make. The first has to do with the second paragraph, "Interior Dimensions." It now reads: "The interior dimensions shall not be less than those shown as standard for tunnels, AREA clearances." The Roadway Committee in presenting their report, submitted or proposed a wording which we are agreeable to accept in lieu of what is shown under No. 2. It reads as follows: "The interior dimensions of clear space provided for single and double track tunnels shall not at any point be less than tunnel clearance approved by the AREA."

In the plans attached to these specifications, pages 646 and 647, we have made reference to vertical drainage. In order to make the plans conform with the text covering the drainage openings in paragraph 8 of these specifications, we wish to add, after all references to tile drains, "where necessary."

There is one other slight correction that appears in reference to the steel liner plate section for double track. You will note that it says, "Steel rib 6 in. min." This is to be changed to "8 in. min."

I almost overlooked another important matter. We have been trying to keep up with the Committee on Clearances. In the report that was prepared last year we thought that we had our clearances as shown in the plan in conformity with the Committee on Clearances. We found that we were in error and we changed it to conform with the clearances for tunnels as now shown in our Manual. We now understand the Committee on Clearances is coming back this year and changing the clearances for tunnels to what we had shown last year, so that now we want to get back to what we had last year in order to conform to what the Clearances Committee is going to propose for tunnels this year. I hope that is clear. That will mean one correction on the plan. It has to do with the vertical distance above the top of rail to the springing line. The distance between the top of rail and the springing line which is now shown as 16 ft. 0 in. will be changed to 15 ft. 0⅞ in. That will be changed on all of the plans for tunnels shown herewith.

I make a motion that they be accepted as shown here with the corrections as mentioned for printing in the Manual.

The President:—It has been moved and seconded that the information be approved for publication in the Manual.

(The motion was regularly seconded, put to vote and carried.)

Chairman M. Hirschthal:—The next part of the report is included in Appendix F, Subject 8, "Design of Expansion Joints Involving Masonry Structures." The report consists of recommended expansion joints resulting from a questionnaire, wherein both the joints and the results of the questionnaire are inserted between pages 650 and 651, including 651, 652, 653 and 654.

The Sub-Committee feels that a specification for a design of expansion joints is not feasible, not practicable, and therefore recommends that this be received as information and the subject be discontinued. I so move.

The President:—The report will be received as information. The Board of Direction will decide on the recommendation of the Committee as to discontinuance of the subject.

Chairman M. Hirschthal:—The next subject is contained in Appendix G, "Study Specifications for Overhead Highway Bridges."

As you have heard earlier in the day, the State Highway Officials have just issued a new specification, so that all our work and criticism of the old specification has been nullified and this subject will have to be started over again. The Committee reports progress and asks that the subject be continued for further study.

This concludes the Masonry Committee's report.

The President:—Mr. Hirschthal, I want to congratulate you on your report. May I say also that a great deal of skill has been displayed and much time spent by this Committee in connection with its work on Manual revision. The Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON WATERPROOFING OF RAILWAY STRUCTURES

(For Report, see pp. 655–664.)

Mr. J. A. Lahmer (Missouri Pacific):—The report of this Committee begins at page 655 of Bulletin 384 and consists of four parts.

The first part relates to Revision of the Manual. There is a very slight change for the purpose of specifying the width of the strip of insulating paper that is to be used at construction joints. The present specifications as adopted heretofore call for "a strip of insulating paper." We are clarifying that by changing to "a strip of insulating paper 18-in. wide." I move the adoption of this change.

(The motion was regularly seconded, put to vote and carried.)

Chairman J. A. Lahmer:—The second part consists of "Principles Governing the Waterproofing or Dampproofing of Railway Structures." It is found in Appendix A, and is offered for adoption in the Manual. I will ask Mr. Dalstrom to present the report.

Mr. O. F. Dalstrom (Chicago & Northwestern):—"Principles Governing the Waterproofing or Dampproofing of Railway Structures" was published two years ago as information and submitted last year for inclusion in the Manual. The subject was referred back to the Committee with the request that certain points be reconsidered. Among the matters to be reconsidered were the comments as to the object of waterproofing regardless of whether the structure is over streets and subways or not. We had the following comment from Mr. Hirschthal: "I have always felt that waterproofing is to prevent deterioration of concrete through the percolation of water through the concrete and corrosion of steel reinforcement on its way out."

The Sub-Committee took this matter under consideration and found that the matter had previously been thoroughly canvassed by the Sub-Committee. It made a report to the Main Committee on the subject recommending no change. The action of the Sub-Committee was sustained by the Committee. A further comment was received from Mr. Coburn. I will not read all of Mr. Coburn's comments as they are rather extensive. They did not contain any definite recommendation on which we could act. However, we considered his points and no changes in the specifications were recommended.

Further comments were received with regard to buildings, the communication reading as follows: "The Sub-Committee which prepared 'Principles Governing Waterproofing or Dampproofing' was requested to consider waterproofing and dampproofing parts of buildings not specifically mentioned in 'Principles' such as parapets, walls, reservoirs, tanks, sewers and walls on which plaster is directly applied, etc."

This article the Sub-Committee found it necessary to expand and the changes which were recommended by the Sub-Committee and adopted appear on page 658 under "Walls and Floors of Buildings." The additional paragraph reads as follows:

"Dampproofing should be applied to the back and top (under coping) of parapet walls and to the back and to the embedded surfaces of architectural masonry trim; also, to the inside of exterior masonry walls if plaster is to be applied without furring."

The rest of the paragraph, which was not changed, is as follows: "Special attention should be given to all joints and to places where pipes or other facilities pass through walls."

Another change is in paragraph 11, "Platforms, Walkways and Roadways." The change consisted in introducing the following paragraph: "Platforms, walkways and roadways over rooms or spaces used as adjuncts to buildings should be waterproofed."

All the rest of this part of the specifications has already appeared twice in Bulletins. I do not believe it is necessary now to go into it any further, even to the extent of reading the sub-headings, unless there is a request for it.

I move the adoption of Appendix A, "Principles Governing the Waterproofing or Dampproofing of Railway Structures," for printing in the Manual.

The President:—It is moved and seconded that the report of the Committee with respect to dampproofing be adopted for printing in the Manual.

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western):—I just want to put myself on record as feeling the same way as I did when I made the comment, that it does not make any difference whether the reinforced concrete structure, slab or otherwise is over a street or subway where any possible leakage would drain on the passerby, or whether it is perfectly dry. The object of waterproofing is to protect the reinforced concrete structure from deterioration and possible destruction and to reduce maintenance of the structure. I still feel that where it is necessary in one case it is necessary in the other. I am not going to make any motion but I simply wanted to state this for the record.

The President:—Gentlemen, you have heard the motion.

(The question was put to vote and carried.)

Chairman J. A. Lahmer:—The third part of the report is on the subject, "Waterproofing and Dampproofing as Applied to Existing Railway Structures." This report is in Appendix B and is self-explanatory and is submitted as information.

The President:—It will be so received.

Chairman J. A. Lahmer:—The last part relates to "Specifications for Bituminous Emulsions," both material and application. This is in Appendix C and is submitted as information. I wish to say that the Committee is continuing this study. We have, even since the preparation of this report, received considerable information from producers regarding various types of emulsions. We now have considerable information from different sources which does not agree, and we expect to sift it and present something definite one year from now.

This ends our report.

The President:—The Committee has presented a very satisfactory report, and are now excused with the thanks of the Association (Applause.)

DISCUSSION ON HIGHWAYS

(For Report, see pp. 577–592)

Mr. G. P. Palmer (Baltimore & Ohio Chicago Terminal):—Both Mr. Brennan, the Chairman, and Mr. Blum, the Vice-Chairman, being absent, I have been asked to present the report.

The report of the Committee on Highways will be found in Bulletin 384, pages 577 to 592. The Committee reports progress on Subjects 2, 3 and 4.

For subject, Revision of Manual, pages 578 to 588, I will ask Mr. Gault to present that report.

Mr. P. M. Gault (Missouri Pacific):—The assignment, "Revision of Manual," will be found starting on page 578 of Bulletin 384. There are one or two typographical errors I should like to call your attention to and ask that they be corrected. The present form is shown in one column and the proposed form in the parallel column. If you will refer to paragraph 2 (b), we should like to have that revised to read: "Fig. 2 and 3—reflector crossing sign assembly may be used with Fig. 1 instead of the painted crossbuck sign where adequate protection is not provided by the painted crossbuck sign, but where automatic signal protection is not required."

Then, on the drawings, pages 580 to 587 inclusive, there should be a note: "These drawings are Signal Section Manual Drawings." There should be a note just below the border line on each one. The note should read as follows: The Fig. 8 note should read: "Material shall be in accordance with Specifications 1630, 12022 and 15533." The Fig. 9 note should read: "Material shall be in accordance with Specifications 15533 and 15633." The Fig. 10 note should read: "Material shall be in accordance with Specifications 15533 and 15633." The Fig. 11 note should read: "Material shall be in accordance with Specifications 1630, 12022 and 15533."

Also on Fig 11 there should be an asterisk and the words, "See 1650 for details." That asterisk you can find on the drawing opposite the name of the figure on the numbered track sign.

On Fig. 12, the same asterisk and a note: "See 1650 for details," and then the specification note: "Material shall be in accordance with Specifications 15533 and 15633."

On Fig. 13 the note should read: "Material shall be in accordance with Specifications 1630, 12022 and 15533."

On Fig. 14 the note should read: "Material shall be in accordance with Specifications 15533 and 15633."

On Fig. 15 the note should read: "Material shall be in accordance with Specifications 15533 and 15633."

These notes are necessary in order to tie these drawings in with certain Signal Section specifications to which they refer.

Then there is one drawing which is now in Manual omitted from this report. In Bulletin No. 2 of the Joint Committee on Railroad Highway Grade Crossing Protection there is a drawing shown as Fig. 16 which, to all intents and purposes, is the same thing as we now have in the Manual, but it is drawn to a little better scale and the signals are designated by name. I would ask that this drawing be included in the report and made a part of the Manual in place of the similar drawing which now appears in the Manual.

The President:—If there is no objection, it may be so altered.

Mr. P. M. Gault:—Getting back to this specification on page 579, at the top of the page is the sub-title, "Flashing Light Type." It is suggested by the Committee that an asterisk be placed after this title and that at the foot of the page or as may be convenient when the report is printed and edited, this note in reference to the asterisk: "Where permitted or required by governmental authority a rotating disk bearing the word 'Stop' in reflector lens may be used instead of the 'Stop on red signal' or the illuminated 'Stop' sign."

I move that this be accepted for inclusion in the Manual.

The President:—Gentlemen, you have heard the report of the Committee. Certain changes have been recommended. Unless there is objection they will be included as part of the Committee report. The question is now on acceptance of the report. Are you ready for the question?

(The question was put to vote and carried.)

Mr. G. P. Palmer:—The fifth subject is: "Difference in Costs of Highways of various Types Due to Different Weights and Lengths of Trucks." This subject will be found on page 589. The Committee desires to eliminate certain sentences in this report as follows:

In the fourth paragraph, line 6, eliminate the words: "However, regardless of this, there is a total lack of agreement among these authorities. This may be explained in large part by." Then a change, starting there, leaving in the sentence reading "The complexity of the problem," eliminating the word "which" and retaining balance reading "is comparable with that of determining definitely how much stronger track must be for an E-75 locomotive than for an E-50 engine." Eliminate the balance of that paragraph.

The Committee also recommends eliminating the last sentence in the fifth paragraph.

With these changes the Committee recommends that this report be accepted as information and the subject discontinued.

Past-President D. J. Brumley:—I should like to ask a question about the remaining sentence in the fourth paragraph. In one case the reference is to an E-75 locomotive and in the other to an E-50 engine. What is the difference between a locomotive and an engine?

Mr. G. P. Palmer:—There really is none. It may be changed if desired. We can call it "locomotive" in both cases.

The President:—The report is presented at this time as information only. It is for the Board of Direction to determine whether the subject shall be continued or dropped. This is the customary procedure. The Committee and the convention may rest assured that before reaching a decision the Board will give due consideration to the views which have been expressed on the subject.

Mr. G. P. Palmer:—Just one more. Sub-Committee 6, "Automatic Pumping Stations for Use in Connection with Elimination of Grade Crossings," shown as Appendix D on pages 590 to 592.

On the top of page 591 appears, "The attached graph." That graph was not attached but it has been printed and I have a copy of it here. Anyone who desires it can obtain it from the Secretary's office to complete the report.

Appendix B on page 588, "Comparative Merits of Various Types of Grade Crossing Protection." The Committee recommends that that report be received as information.

The President:—It will be so accepted.

Committee IX—Highways is growing in importance. It is difficult at this stage to fully evaluate the opportunities before this Committee for real pioneer work on matters which relate both to highways and to railways. Many of the problems appear to lie in the field of fundamental science and it is becoming increasingly apparent that their ultimate solution must profoundly affect existing practices, particularly in land transportation and development.

In the name of the Committee I invite the members of this Association to contribute information or suggestions they may have on the general subjects which lie within the scope of the work of this Committee. Preferably it should be sent to the Secretary of the Association, who, in due course, will forward it to the Chairman of the Committee for consideration by the proper sub-committee for such action as the circumstances warrant.

Mr. Palmer, your Committee is now excused with the thanks of the convention (Applause.)

DISCUSSION ON WATERWAYS AND HARBORS

(For Report, see pp. 219–233)

Mr. G. P. Palmer (Baltimore & Ohio Chicago Terminal):—The report of the Committee on Waterways and Harbors will be found in Bulletin 382, pages 219 to 233.

The report of Sub-Committee 3 on "Suitable Types of Construction for Levees, Dikes and Mattresses for Use Under Varying Service Conditions," and so forth, will be found on pages 222 to 229 and is offered as information, with the recommendation that the subject be continued for a final report upon suitable types of dikes and mattresses.

Before proceeding further, however, I want to say that Col. Andrew Perry Wenzell, Special Engineer of the New York Central, Chairman of this Committee, died very suddenly on September 22. Colonel Wenzel was one of the finest men that I ever knew. He contributed freely of his time and talents in the reports of the various committees of this Association, and in his death the Association has lost an esteemed and valuable member.

On subject 4, Types of Breakwaters, Bulkheads, Jetties and Seawalls, giving cross-sections of each and stating purpose which they serve, the Committee reports progress.

For subject 5, "Types of Warehouse Piers, Coal Piers, Cart Float Piers," and so forth, the Committee reports progress.

On subject 6, "Size and Depth of Slips Required for Various Traffic Conditions," we report progress.

Under Sub-Committee 1, "Revision of Manual," the Committee recommends that the specifications for the construction of the several types of river bank protection in common use, as shown in Supplement to the Manual, Bulletin 379, page 92, be deleted; that the definitions of terms, as given in Appendix B, be deleted.

This is recommended so that only definitions of words or terms the meaning of which is not clearly established or that have a peculiar meaning when applied to the subject matter of reports by this Committee, are to be retained, so that when the new Manual is published we will have in there only the definitions of words that we use in this Committee.

I make a motion that the revision of the Manual as recommended be made.

The President:—It is moved and seconded that proposals for revision of the Manual as reported by the Committee be adopted.

(The motion was put to vote and carried.)

Mr. G. P. Palmer:—Sub-Committee 7, "Economic Principles Involved in Clearances over Navigable Waterways." It is recommended that this report be received as information, shown in Appendix D on pages 229 to 231.

Also, that Sub-Committee recommends that the resolution appearing in Appendix D be adopted and published in the Manual. I will ask Mr. Brumley, Chairman of the Sub-Committee, to make the report on that.

Past-President D. J. Brumley:—The report to which our Chairman refers is to be found on page 229 of Bulletin 382 and consists of two parts. The first relates to the methods of processes followed by U.S. Army Engineers in making investigations and reports on waterway projects, whether these projects are for the improvement of navigation, flood control, or irrigation.

This is somewhat of an amplification of our report of last year and outlines in some detail the methods of procedure which are not generally understood.

The report also emphasizes the desirability of working with the U.S. Army Engineers during the preliminary stages of their studies. In general, those Engineers are not always familiar with all the local conditions surrounding railway property and will accept data as to railway gradients, depths of foundations, bridge loadings, current construction costs, and other factual data in the railway company's files. This data will not only be helpful to the District Engineer's office, but may likewise obviate erroneous conclusions. Contact with the District Engineer's office will present the opportunity for the railway to obtain data on the scope of the project, and the resultant effect the carrying out of the project will have on the existing railway plant.

The most important thing of all is to get the railway's situation clearly before the District Engineer, and while his report is in the process of formulation. This will lay the foundation for the representations to be made by the railway at the public hearing at a later date.

These contacts with the District Engineer offer the best opportunity of discussing with him the principles on "Public Improvement Projects—Their Costs and Benefits," adopted by this Association a year ago and now a component part of the Manual.

This report also stresses the desirability or rather the necessity of getting the railway's case clearly, logically and effectively before the District Engineer. The showing thus made by the railway becomes a part of the record forwarded by the District Engineer to his superior officer and finally lands in the office of the Chief of Engineers.

The second part of the Sub-Committee's report deals with the subject-matter contained in a resolution adopted by the Association as its annual meeting in March, 1934, Proceedings Vol. 35, page 1194. That resolution reads:

> "That proper clearances for navigable streams are those which will not unduly interfere with the operation of either land or water transportation, cause unwise expenditures to be made for physical readjustments, or place burdensome restrictions on their future expansion. There must be an economic balance in the interest of both forms of transportation."

The activity of Federal and State governments on waterway projects is a matter of grave concern to railway transportation agencies, and has also awakened the interest of other engineering societies. During the past year your Committee has collaborated with like Committees representing the American Society of Civil Engineers and the Western Society of Engineers. At the annual meeting of the American Society last January, that engineering association adopted a resolution, including a recommendation for a catalog or listing of all bridges over navigable waterways, as well as "Clearances over navigable waterways," the latter resolution reading as follows:

> "Proper clearances for structures over navigable waters are those that will not interfere with the operation of either land or water transportation, cause unwise expenditures to be made for physical readjustments, or place burdensome restrictions on their future expansion. There must be an economic balance in the interest of both forms of transportation."

This is in the same language as contained in the Sub-Committee's report. Since the prospects are that the waterway problems will continue to be notably pressing in the immediate future, and will always be before the railways, your Committee recommends the approval of the following resolution for publication in the Manual:

"Proper clearances for navigable waters are those that will not interfere with the operation of either land or water transportation, cause unwise expenditures to be made for physical readjustments, or place burdensome restrictions on their future expansion. There must be an economic balance in the interest of both forms of transportation."

The President:—You have heard the recommendation of the Committee. It is moved and seconded that the changes as recommended by the Committee be adopted for printing in the Manual.

(The motion was put to vote and carried.)

Mr. G. P. Palmer:—The report of Sub-Committee 8 on "Cost to Railways for Construction, Maintenance and Operation of Bridges Over Navigable Waterways" will be found on pages 232 and 233 and I will ask Mr. F. E. Morrow, Chairman of this Sub-Committee, to make the report.

Mr. F. E. Morrow (Chicago & Western Indiana):—The report of your Sub-Committee is found in Bulletin 382. "Last year the Committee presented a form to be used by the railroad companies in compiling data on the cost of construction, maintenance and operation of bridges over navigable waterways. This form was presented as information only inasmuch as it was felt desirable to give the matter further consideration.

The Committee has changed the proposed form to a questionnaire entitled "Railroad Structures Over Navigable Streams or Waterways in the United States." The Committee has had the benefit of suggestions made by Dr. C. S. Duncan, Economist, Association of American Railroads, in its preparation.

It has been the purpose of the Committee to prepare a questionnaire which would develop the information needed to ascertain the costs which are borne by the railroads on account of the navigation requirements on streams and waterways. It is believed that the attached questionnaire will develop that information in a uniform manner and it is recommended for approval, but not for publication in the Manual.

The President:—Gentlemen, you have heard the recommendation of the Committee. It is moved and seconded that it be adopted for use by the Association.

This form is needed at this time for the collection of certain factual data from the railways, concerning the extent and costs for construction, maintenance, and operation of railway bridges over so-called navigable waterways which are actually not so in fact.

Excellent progress has been made by your Committee on this subject. It has shown the need for some corrective action or modification of existing practices with respect to such problems. However, before much further progress can be made in the way of definite recommendations by your Committees, it will be necessary to have additional information on the subject. This is the purpose of the form.

(The motion was put to vote and carried.)

Mr. G. P. Palmer:—That completes the report of the Committee on Waterways and Harbors.

The President:—Mr. Palmer, Committee XXV, like the one preceding, IX, is among the most important committees of this Association. Committee XXV has done excellent work and is now excused with the thanks of the convention (Applause.)

DISCUSSION ON RECORDS AND ACCOUNTS

(For Report, see pp. 593–630)

Mr. C. C. Haire (Illinois Central):—The report of the Committee on Records and Accounts is found on pages 593 to 630 of Bulletin 384. Our subjects have been grouped under six sub-divisions. You will notice the sub-divisions of these groupings.

The first report is on the Revision of Manual. Mr. Stroebel, Chairman of the Sub-Committee, will present the report.

Mr. H. J. Stroebel (Erie):—The Committee has made a thorough study of the Manual and Supplements of the chapter on Records and Accounts and, in the light of the proposed general revision in 1936, has, in order to more fully embrace the scope of the section and subject-matter, rearranged the grouping and general headings.

The study has developed the need of dividing the chapter into four major sub-divisions, namely: A General Records and Reports; B Construction Records, and I want to add in there, and Reports; C Maintenance of Way Structures and Reports; D Property Records and Reports. These to be further divided into appropriate subjects coming under each of the above general subjects.

In order to arrange the material in accordance with the above sub-divisions and to bring the Manual up to date, it is necessary to eliminate obsolete matter from the Manual and Supplements, to revise certain existing material and to introduce new matter previously offered as information, and now intended for inclusion in the Manual. The following is a list of such recommended changes:

(1) Under the heading of "Definitions." Delete word "appraised" in definition of "Salvage," and the two definitions for "payroll," on page 81, Bulletin 337, Supplement to the Manual.

(2) Office and Drafting Room Practices. Graphical Symbols, Vol. 36, 1935, pages 391 to 396, inclusive, are recommended for inclusion in the Manual.

(3) Specifications for Preparation of Maps and Profiles, Vol. 36, 1935, pages 384 to 388 inclusive. It is the recommendation of your Committee that these specifications be included in the Manual.

(4) Joint Facility Records. The Committee has revised the text of the report shown in Vol. 34, 1933, page 234, Vol. 35, 1934, pages 603 to 609 inclusive, and Vol. 36, 1935, pages 398 to 399, in order to condense the material for the Manual. The revised text is shown as Exhibit 1.

It is recommended that the revised text, together with forms and charts shown in the above volumes, be adopted for inclusion in the Manual.

(5) Track Chart. It is the recommendation of your Committee that the insert of the track chart, shown opposite page 740 of the Manual, be deleted, and that the revised chart shown as Exhibit 2 be substituted.

(6) System of Reports and Records Required to Budget and Control Maintenance of Way Expenses. The text of the report shown in Vol. 36, 1935, pages 400 to 406 inclusive, has been revised in order to condense the material for the Manual. It is recommended that all of the text on page 768 of the Manual and part of that on page 769 to the section headed "Control Through Economy of Maintenance" be deleted and the revised text, together with the forms, Exhibits 1, 2 and 3 shown in Vol. 36, be adopted for inclusion in the Manual. The revision of the text is shown as Exhibit 3.

Chairman C. C. Haire:—I move adoption of the changes.

The President:—It is moved and seconded that the changes recommended by the Committee be adopted and printed in the Manual.

Mr. Frank Ringer (Missouri, Kansas & Texas):—I should like to ask the Chairman of the Sub-Committee what is the essential difference in the track chart shown from the one now in the Manual and what the purpose of the Committee was in making the change.

Mr. H. J. Stroebel:—The purpose of changing the track chart was this: The track chart as now in the Manual consists of a long sheet folded two times. It is also an old sheet, and it shows weights of rails which are practically obsolete now. We brought the milepost designations into accord with the revised track symbols, and the same is true for the designations for ballast and rail. On trackpans, for instance, we have changed the profiles to show that the trackpans are on a level track whereas before they were on a grade of 1 per cent. The chart has been condensed mainly to bring it on one page and up to present-day practice.

Mr. Frank Ringer:—You have answered my questions.

The President:—It has been moved and seconded that the changes recommended by the Committee be adopted and printed in the Manual.

(The motion was put to vote and carried.)

Chairman C. C. Haire:—Our next subject is "Bibliography on Subjects Pertaining to Records and Accounts." The bibliography pertaining to records and accounts is a report that appears each year and we are merely calling attention to outstanding books and publications in our field of work.

There is one of the members of our Committee to whom I should like to call your attention. He has written a book of fiction. We ordinarily do not review works of fiction, but Mr. Frank J. Nevins, a member of our Committee has written an historical novel. Probably some of you have read it. It is entitled "The Yankee Dared." We recommend that book to you as having some historical value and it makes very good reading.

This report is offered merely as information.

The President:—It will be so received. There is some very excellent material in these reports. I trust that the members of the Association will take advantage of the fact.

Chairman C. C. Haire:—Our next subject, "Office and Drafting Room Practices," appears under Appendix C. Due to the absence of the Chairman of the Sub-Committee, I will present the report in his place. This Committee has been at work for several years devising symbols, and heretofore we have published similar material, some of which has been adopted for inclusion in the Manual. We now offer a number of additional plates, 15 in number, that you will find in this Bulletin. It is offered this year as information. The Chairman of the Sub-Committee and one of its members have been acting on a Joint Committee of this Association with the Signal Section, Electrical Section, and the T&T Section. Their object is to get out a symbol book, and this work you see here is a step in that direction to be used by the Joint Committee.

Naturally, in a work of this kind we will need the help of every committee which has any ideas on symbols and drawings or drafting room practice, and we should like to ask that you criticize this material very closely. This report is offered as information this year.

The President:—It will be so received.

Chairman C. C. Haire:—Our next subject is "Recommended Practice to be Followed with Respect to Maintenance of Way Accounts and Statistical Requirements," Appendix D. This is a subject that we have had with us for many years. Our object is to get into the records of the Association a complete routine of accounting and statistical records. The Chairman of the Sub-Committee, Mr. Cummings, unfortunately, is not here. He was here the first day but had to return to Boston. I will call your attention to some of the outstanding things we have in mind. Exhibit 1 is an outline of what has been done by this Sub-Committee and its ultimate objective. You will notice that this year we have prepared three forms, and this report is offered as information.

The President:—It will be so received.

In connection with the report of this Sub-Committee I desire at this time to point out to the convention that much valuable aid can be given to Committee XI by members of this Association, and in their name I solicit your assistance.

It is believed by many students of transportation that public demands for increasingly faster railway service, with all its attendant requirements, must more or less influence existing practices for recording, accounting and other related matters, and particularly so in the interests of simplicity, economy, and increased efficiency. In addition to its definite assignments, Committee XI desires to remain in a position that through its activities this Association may in turn be responsive to such trends if they should in fact appear.

If during the year you have any information or views on the subject it would be appreciated by the Board of Direction if you will send them to the Committee, preferably through the Secretary of the Association.

Chairman C. C. Haire:—Our next subject appears on page 621, "Construction Reports and Records." This is the first report under this group and you will notice that we have reported upon several subjects. What we propose to do in connection with the type of report is to design a system of records and reports that should be in the possession of a well-organized engineering department. It is supposed to supplement the valuation and accounting records, although there is no costs shown as connected with this type of report.

We offer this report as information this year.

The President:—It will be so received.

Chairman C. C. Haire:—Our next subject is the Valuation subject, page 625. For many years this Committee has had before it the same subject. It is changing in character. You will notice from the text of the report that during the last year we put into effect a plan of cooperation with the Bureau of Valuation and a plan of cooperation with the Finance, Accounting, Taxation and Valuation Department of the Association of American Railroads. Heretofore this Committee has found it difficult to contact the Bureau of Valuation direct, but under the new plan we work very closely with Mr. Bunnell's department, and we have been able to sit in conference with Director Lewis and his staff, and hope that something helpful will come out of it, something more practical, and ease the burden of valuation requirements. We expect to continue this form of cooperation and to keep the Association advised in detail of everything that takes place.

This report is offered as information.

The President:—It will be so received.

Chairman C. C. Haire:—Under this group the Committee has had another assignment, Depreciation Order 15100. As most of you know, that Order has been postponed indefinitely, and consequently the Committee has not prepared any report covering the subject. This does not mean that the Committee has subsided in its interest in studying the subject. We have prepared a voluminous report, some 160 pages, and we hope sometime it will be available to the Association, but for policy reasons and the fact that much of the subject is controversial, we have not insisted that it be published.

The subject of depreciation, however, as most of you know, is something that we probably will be faced with in the future, and right at present there is considerable need for information for tax purposes and valuation purposes. For tax purposes, the question of depreciation is particularly vital in income tax cases. We hope that conditions will permit the publication of this report in the near future.

During the year President Ford gave much attention to establishing contact between this Association and the Finance, Accounting, Taxation and Valuation Department of the Association of American Railroads. The Committee appreciates the effort made to establish contact with these people and to work out some cooperative plan that will be helpful to both organizations. I think Mr. Ford has laid the groundwork for future favorable developments in this direction.

The report is offered as information.

The President:—It will be so received.

I may say, however, that the Chairman is too modest. The President of this Association was merely acting as a sort of instrumentality in support of the consistent efforts of Chairman Haire and his excellent Committee. For several years this Committee, with the assistance of the executive officers of the Association and the approval of the Board of Direction, endeavored to establish suitable cooperation between the American Railway Association and its successor, the Association of American Railroads (through its Department of Finance, Accounting, Taxation, and Valuation) and in this way, enable the official agencies of the railroads to become more closely familiar with the wide range of activities of this Association.

The personnel of Committee XI—Records and Accounts, includes men of recognized standing in the engineering profession who are also especially qualified in accounting and valuation. The Committee recognizes that there are many problems of the railways within this field where engineering and economics are in reality involved and where they feel it would be to the interest of all concerned if our Engineers could more actively participate in their solution. I am sure that through the agency of this Committee and the contacts which have already been established, still greater progress will soon be made in this direction.

Mr. H. M. Stout (Northern Pacific):—May I interrupt the Committee report? It may be a little unusual to speak during the presentation of a committee report, but the Chairman's remarks about having a voluminous report on this very important and intricate subject of depreciation prompts me to recall something that took place the first day of this convention. It is unfortunate, it seems to me (maybe that is too strong a word)—at any rate I think it would have been advantageous if this Committee had risen to the opportunity then offered and presented their views on the subject of depreciation in connection with the Roadway Committee's report on (3) Service Life of Culverts. There were some criticisms presented, some pertinent questions asked that committee at that time, and this Committee might have assumed the function of a brake upon that committee's presentation. The values that they were offering or suggesting, it seems to me, were not properly supported in the experiments and the studies that we have made; and I think that this Committee probably out of the very voluminous report which they have prepared and are holding in reserve on railway service might have been used to some advantage to the Association.

Mr. E. L. Crugar (Wabash):—I might say, along that line, since this discussion has come up, that the Committee on Outline of Work is going to arrange for some collaboration during the coming year on that subject.

The President:—Mr. Stout, does that answer your inquiry?

Mr. H. M. Stout:—I think the plan they have in mind is a very excellent one.

Chairman C. C. Haire:—On page 628 we have a report on the subject, "Changes or Revisions in I.C.C. Classification of Accounts." The subject, naturally, is closely allied to the depreciation subject, but there are so many changes taking place these days that the Committee is undertaking to report to the Association the developments. Mr. Kettenring, Chairman of the Sub-Committee, will present the report.

Mr. W. R. Kettenring (Chicago & Northwestern):—In the past several years there have been quite a few orders issued by the Bureau of Accounts of the Interstate Commerce Commission and two orders were issued during the year 1935 changing the provisions of the current Accounting Classifications. The order of most interest to Railway Engineers was issued under date of September 16, 1935, and dealt with the accounting for ballast.

The principal changes resulting from this order are:

(a) The establishment and definition of ballast sections and the requirement that a continuing record be maintained of ballast in place.

(b) The distribution to investment account of the expense of placing additional ballast.

(c) The classification of ballast in three major groups.

(d) The handling of ballast of a superior grade placed in lieu of ballast of an inferior grade as property retired and replaced.

It appears that the continuing ballast record required by the Order may be in either statement or graphic form. In some cases present records will be adaptable, but it is probable in the majority of cases new records will be required to meet the requirements of the Order. The preparation of these records can doubtless be deferred in many districts, pending application of additional ballast in such districts.

The change in the Accounting Classifications has the effect of charging to investment account the current cost of placing additional ballast which, under rules previously affected, would have been charged to operating expenses. It also eliminates accounting for ballast under the so-called "Betterment" method of accounting, and provides that the cost of ballast replaced by other ballast of superior grade shall be retired at its original cost, and the cost of the new ballast charged to investment account. This is an improvement, as it is difficult to properly represent the cost of any property where betterment accounting is involved.

The Sub-Committee's report, then, contains a copy of the Ballast Order which it is unnecessary to read here at this time.

By another and previous Order of the Commission, dated May 28, 1935, effective June 1, 1935, the I.C.C. prescribed a more elaborate form of income statement than that shown in the Classification previously effective.

A copy of this Order is not inserted, as it is thought those particularly interested in the subject can secure copies of same.

That was the status of the Accounting Order at the time the Committee's report was made and prepared for the printer. I have a text here which is rather voluminous. I should like to read a couple of paragraphs of it and then insert the rest as information in the Proceedings:

After the preparation of the Sub-Committee report as outlined in Bulletin 384, the Commission issued an order dated December 20, 1935, postponing for one year the effective date of the change in accounting for ballast. Unless further postponement is made, the revised accounting for ballast will become effective before the next convention; and it seems appropriate to suggest that this order be studied jointly by representatives of the Committee on Ballast and the Committee on Records and Accounts, and a report prepared on the procedure necessary to meet the requirements of this order.

An Order covering further changes in the Classifications for Road and Equipment, Operating Expenses, and Income Accounts was issued under date of December 27, 1935 and effective January 1, 1936.

While the latter Order should be studied in its entirety by anyone directly concerned with the accounts, the following summarization covers the principal changes in the distribution of cost of constructing and maintaining road property.

Account 2½—OTHER RIGHT-OF-WAY EXPENDITURES.—This is a new account to which will be charged expenditures by the carrier in excess of the cost of transportation property acquired. This will include farm passes, both grade and undergrade (excluding structure carrying tracks), pipe lines, drains and other facilities across the carrier's right-of-way.

Account 13—FENCES, SNOW SHEDS, AND SIGNS.—This is a new account to which will be charged expenditures heretofore charged to:

Account 13—Right-of-way fences.

Account 14—Snow and sand fences and snow sheds and that portion of Account 15—Crossings and signs, covering cost of track and highway signs.

Account 15—CROSSINGS AND SIGNS.—This account has been cancelled, and expenditures heretofore charged to this account will be distributed to the following accounts:

Account 39—Public improvements—Construction—Street surfacing, paving, curbing, culverts, planking, street lighting systems and overhead highway bridges.

Account 27—Signals and interlockers—Crossings signals, crossing gates, flagmen's cabins, elevated gate towers, etc.

Account 13—Fences, snow sheds and signs—Crossing and track signs.

Account 2½—Other right-of-way expenditures—Farm crossings, both grade and undergrade (excluding structure carrying tracks).

Account 27—SIGNALS AND INTERLOCKERS.—The expenditures for protection of traffic at crossings, such as flasher light signals, gates, warning bells, flagmen's cabins and gate control towers, will be charged to this account, in addition to the signal items heretofore included.

Account 29—POWER PLANTS.—This account will include expenditures heretofore charged to:

Account 28—Power dams, canals, and pipe lines.

Account 29—Power plant buildings.

Account 30—Power substation buildings.

Account 31—POWER-TRANSPORTATION SYSTEMS.—This account will include expenditures heretofore charged to:

Account 32—Power distribution systems.

Account 33—Power line poles and fixtures.

Account 34—Underground conduits.

Account 39—PUBLIC IMPROVEMENTS—CONSTRUCTION.—This account will include expenditures heretofore charged to Account 39—Assessments for public improvements, Account 36—Paving, and in addition planking, paving, sidewalks, drainage, etc., at highway crossings, and overhead highway bridges, including approaches.

Account 45—POWER-PLANT MACHINERY.—This account has been expanded to include expenditures heretofore charged to Account 46—Power substation apparatus.

OPERATING EXPENSES.—The following accounts in the operating expense classification are cancelled, together with the corresponding depreciation accounts:

Account 221—RIGHT-OF-WAY FENCES.

Account 223—SNOW AND SAND FENCES AND SNOW SHEDS.

Account 225—CROSSINGS AND SIGNS.

Account 251—POWER PLANT DAMS, CANALS, AND PIPE LINES.

Account 253—POWER PLANT BUILDINGS.

Account 255—POWER SUBSTATION BUILDINGS.

Account 259—POWER DISTRIBUTION SYSTEMS.

Account 261—POWER LINE POLES AND FIXTURES.

Account 263—UNDERGROUND CONDUITS.

Account 267—PAVING.

Account 306—POWER SUBSTATION APPARATUS.

Appropriate changes are made in the following accounts to make them conform to the changes in the investment account:

Account 221—Fences, Snowsheds, and Signs.
Account 222—Fences, Snowsheds, and Signs—Depreciation.
Account 249—Signals and Interlockers.
Account 253—Power Plants.
Account 257—Power-Transmission Systems.
Account 304—Power-Plant Machinery.

Two new accounts are added to which will be charged the maintenance of improvements charged to the investment accounts:

Account 2½—Other right-of-way expenditures.
Account 39—Public improvements—Construction.

These new accounts are:

Account 273—Public Improvements—Maintenance.
Account 281—Right-of-Way Expenses.

Other changes are made whereby Revenue Accounts 111—Special service train, is cancelled and expense hereafter lodged in Accounts 101—Freight, and 102—Passenger; Revenue Account 112—Other freight-train, is cancelled, and expense hereafter lodged in Account 101—Freight. Account 382—Yard switching fuel, and Account 394—Fuel for train locomotives, are modified to provide for the general use of motor driven switching and train units.

Other minor changes occur in the Income and Profit and Loss accounts to which it seems unnecessary to call specific attention.

The changes in the Investment Account outlined above are in accord with changes proposed in the last general revision of the Accounting Classifications by the Bureau of Accounts about a year ago. In my remarks on the changes in accounting for equipment and the application of Depreciation Order 15100 to equipment depreciation made to this convention last year, I called attention to the gradual trend toward the application of depreciation to fixed property. The accounting changes in the order now effective and in the ballast order which has been postponed until January 1, 1936, are simply further steps in the movement to make the Accounting Classifications more readily conformable to depreciation accounting.

The present change is very unsatisfactory to those responsible for maintaining the physical records of the carriers, as with the cancellation of certain important accounts, the accounting credits for property replaced or abandoned will no longer be recorded to these cancelled accounts, although the carrier's investment for considerable property is still carried therein, and correction in the physical property records must still be allocated to the old accounts. While the complete revision of the Accounting Classifications would entail a large amount of work on the part of the carrier, it seems that the piece-meal revision will entail a greater amount of work and produce less satisfactory results.

This completes the report.

The President:—I should like to ask Mr. S. S. Roberts if he can contribute anything on the subject. Mr. Roberts, have you any suggestions or can you enlighten the convention on any features of this very excellent report?

Mr. S. S. Roberts (I.C.C., Washington, D. C.):—I think this is a very excellent report. I have no comment to make upon it.

I should like to say, if I may, referring back to the report of the Committee I—Roadway, Appendix D, Bulletin 381, that I am not in accord with that Committee's method of determining average life. It seems to me that the method it uses does violence to all practicable methods of obtaining average life. The Committee took the culverts that were in existence, guessed at the age at which they would be retired, took an average of that, and called it the average life. If that procedure is followed far enough until you get to the last culvert to go out, you might just as well, just as reasonably, call the life of that extraordinarily long-lived culvert, the average life of its particular class.

I think it would be well if the long report of Committee XI—Records and Accounts, on depreciation, not heretofore published, referred to by a previous speaker, should be published so that the Association may have the advantage of the study and the ideas of this Committee on methods for obtaining average life. The correct determination of average life is the backbone and substance of all economic studies.

The President:—Mr. Kettenring, your report shows evidences of careful study and equally careful preparation. It is a worth-while effort and the Association is correspondingly indebted to your Committee. Mr. Haire, have you anything further?

Chairman C. C. Haire:—That concludes the report of the Committee.

The President:—The Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS

(For Report, see pp. 81–98)

Mr. F. L. Nicholson (Norfolk Southern):—The report of Committee XX—Uniform General Contract Forms, will be found in Bulletin 381, page 81, but before presenting the report on the assigned subjects it is my painful duty to advise you of the double loss this Association and Committee XX have suffered in the death of Charles A. Wilson at Cincinnati on June 3, 1935, and Roland P. Eubank at Richmond, Virginia, on October 14, 1935.

Mr. Wilson was a promoter and a Charter Member of this Association. He faithfully and continuously served as a member of this Committee since March, 1909, or for more than 26 years, and during the years 1913 to 1922 as its Vice-Chairman. For this entire period he served with understanding, faithfulness and devotion, and these, together with his genial, friendly personality, his judicial temperament, his contribution of valuable advice resulting from long experience in important engineering and operating problems, greatly endeared him to the members of this Committee.

Mr. Eubank became a member of the Association February 23, 1929, and as a member of Committee XX in April 1930, and faithfully served the Association until October 14, 1935, the date of his sudden death on the streets of Richmond, Virginia. He served as Chairman of a Sub-Committee in 1934–35 charged with the investigation and the preparation of the "Form of Conveyance of Title, Granting the Right to Construct and Maintain Buildings over Railway Property."

Mr. Eubank was one of the Committee's most loyal, active and highly esteemed members, and had a wealth of experience, well fitting him for service on this Committee.

We shall miss them, gentlemen.

Now, taking up the report of the Committee, Subject No. 1 is Revision of Manual. The Committee is presenting certain changes in various adopted forms, in the nature of editing, with the view to uniformity, simplification and convenience in use. The Chairman of the Sub-Committee will present these changes for your adoption, with the recommendation that such changes be made in the forms now in the Manual, to which they apply, at the time of the next printing. The report will be presented by Mr. O. K. Morgan, Chairman of the Sub-Committee.

Mr. O. K. Morgan (Consulting Engineer):—The report of the Sub-Committee will be found in Bulletin 381 on page 83. I will outline the changes recommended as follows:

1. Simplification of titles of six adopted forms.

2. More uniformity of wording in the opening paragraph of each form in describing the parties to the agreement. The changes consist of naming the Railway Company first, describing it as a corporation, etc., and the other party second.

3. Greater uniformity in the contract forms where two railways are parties to the agreement. Three recently adopted forms use "A" Company and "B" Company to aid in understanding the contract. It is proposed to correct three additional forms by the insertion of "A" Company and "B" Company in the blank spaces; printing will also be simplified.

4. Substitution of a uniform Arbitration paragraph for the diverse wording of eight existing paragraphs; one of which calls for three arbitrators; seven call for a sole arbitrator and some forms provide for the Court to appoint the arbitrator if the parties cannot agree. The proposed form provides for a sole arbitrator, Court appointment if the parties cannot agree, and for the allocation of the expense.

5. A large number of existing forms have subheads at the beginning of the paragraph, which are a great convenience to the user. It is proposed to supply subheads to the remaining ten forms and add to their convenience and also make for uniformity.

6. The executory paragraph of existing forms differ widely in wording, without any valid reason. It is proposed to make this clause uniform in the various forms.

What I have given is on page 83. Through an error in some manner the matter of the Sub-Committee is continued on page 91, beginning about the center of the page. I will ask you to turn to page 91.

On pages 91, 92, 93, 94, 95, 96, 97 and 98 are presented the proposed forms embodying the changes, and, I move that these changes be adopted for inclusion in the Manual.

The President:—The Committee recommends the approval of the forms. The question is upon their adoption for printing in the Manual.

(The motion was put to vote and carried.)

Mr. O. K. Morgan:—One other matter. In addition to the printed matter of Bulletin 381, the Committee's attention has been very recently called to the use of the expression "and/or". The use of this expression in legal documents in Illinois has been declared illegal. Its use is severely condemned in the courts of Alabama, Louisiana, Utah, Nevada, by the American Bar Association and other high sources. It has appeared to our Committee to be desirable to eliminate its use from the adopted forms of this Association. It has been used in only three of our 24 adopted forms. The Committee did not succeed in acting on this matter in time to get it published in the Bulletin but since a new Manual is about to be issued it is desirable to make it as near perfect as possible. Our Committee decided to bring the matter before this meeting and to recommend the deletion of the expression "and/or" from its three adopted forms, and the substitution in place thereof of the appropriate word, which is generally "and" or "or," as best suits the case. I so move.

The President:—It is moved and seconded that the expression "and/or" be not used in the future by this Association and the term "and" or "or," as the case may be, be substituted.

Mr. E. M. Hastings (Richmond, Fredericksburg & Potomac):—I think that the Committee has made a very distinct step forward in bringing this rather peculiar subject to the convention. May I, in speaking in favor of this motion of the Committee, say that let us, in the language of the distinguished senior Senator from the state of Virginia, make up our minds which word we are going to use and use one or the other.

The President:—Is there any further question?

Mr. O. K. Morgan:—I do not believe it is necessary for the convention to act upon it. It is largely a matter of editing, but it is also a question, I think, of propriety. I simply call it to the attention of the members because I think it is of some importance. That completes the report.

Chairman F. L. Nicholson:—There are probably one or two places where the substitution of the word "and" or the word "or" will not exactly explain the intent or the meaning of the contract. The Committee has by meeting adopted the proper wording and we ask the approval of the committee's action.

The President:—The question is now on the adoption of the Committee recommendation.

(The motion was put to vote and carried.)

Chairman F. L. Nicholson:—The second subject is the "Form of Agreement with Public Authorities for Highway Grade Crossing Elimination or Separation." At the time of submitting its report last November the Committee recommended the discontinuance of this subject, which recommendation it now withdraws, and in view of the rapidly changing conditions concerning this matter the Committee desires to give it further consideration and will continue its studies for future report.

The President:—Unless there is objection, the Committee will proceed accordingly.

Chairman F. L. Nicholson:—Next is the "Form of Agreement for Cab Stand Privileges." A tentative form of agreement has been prepared and it is submitted as information. At several points in this form the expression "and/or" appears and this will be changed in accordance with the permission given the Chairman of Sub-Committee No. 1.

"Form of Agreement for Store-Door Delivery." The tentative form of agreement is presented as Appendix C on page 85 and embodies, in the judgment of the Committee, the essential terms for such an agreement and is submitted as information.

The Committee desires to call particular attention to this form. It seems opportune. It is a live subject under treatment by railroads throughout the country and we would ask that the membership of this Association call this form to the attention of the proper officers for consideration by their roads. The investigations have been very thorough. All of the forms that were available on this subject have been studied by competent Sub-Committees and there has been a collaboration with the Western General Managers' Association who, we found, had the same subject under consideration, and the form that we now present as information is a result of that work. The Committee believes it is a good job. We have gone to some length in preparation of some of the information but, believing it to be a subject new to most of us, we have tried to cover the field thoroughly.

This is submitted as information, gentlemen, and we hope you will study it. If you have any suggestions to offer that will be helpful to the Committee in preparation of the final report and will send your suggestions to the Secretary of this Association, we will get them and will be very glad indeed to give due consideration.

The President:—It will be so received.

The convention will take note that the Chairman admits his Committee has done a good job.

Chairman F. L. Nicholson:—That completes our report.

The President:—Mr. Korsell, can you contribute anything that would be helpful to the convention in its consideration of the Committee's report?

Mr. A. E. Korsell (Rock Island):—I wish to endorse the work of the Committee in its attempt to unify contract forms. An inspection of several forms of various railroads indicates they are somewhat similar but there is a field for their modification to a certain extent.

In the Committee's consideration of contract forms with particular reference to those relating to highway-railway grade separations, the subject-matter should not be sacrificed to brevity. Contracts that are now being prepared by several states are in many cases at variance both as to subject-matter and form. Some are prepared in great detail and others so general that after their execution, it is difficult at times to determine definitely their intent when certain specific questions arise that may have been previously overlooked.

There is a need for a uniform contract for highway-railway grade separations where they jointly affect the railroads, states or other governmental bodies. One of the most troublesome factors in connection with contracts between the railroads and State Highway Departments is that of securing satisfactory indemnity provisions either in the way of a bond or liability insurance. It may be suggested the Committee give particular attention to the question of indemnity bond or indemnity insurance for embodying in the forms of contracts with the States.

The President:—Are there any further questions?

Chairman F. L. Nicholson:—The Committee would like very much to have the written suggestions of the gentleman who has just spoken. They will be helpful to us, I am sure.

In connection with his remarks concerning the agreement with public authorities for highway-grade crossing elimination, I will advise the Association that through our Secretary we have obtained copies of contracts that have been already executed in the various states of the Union. I think we probably have them all. The Committee is being broken up into three or four Sub-Committees for the study of this matter and the preparation of a form that we hope might be used as a standard form by the Department of Public Roads in cooperation with the state authorities. The review of all these forms is quite a large work but we hope to be able to bring something of value to you by the next convention.

The President:—The Chairman of the Committee has referred to a very important matter. He asks the aid of the Association in the work for the coming year. Changing economic conditions, where a new line of thought is creeping into the public mind generally with respect to the relationship of rail transportation on the one hand and other forms of transportation on the other, and public interest as well, have prompted the need of something of this kind. The convention should be aware of the fact that due to a great many conditions of the past legislation has gone in various directions. The purpose of this Committee is to try to present some salient recommendations that ultimately may perhaps form the basis for Federal and State legislation and corrective work to keep in step with the changing conditions of the times in transportation.

Mr. Nicholson, you have done a good work, and the Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON MAINTENANCE OF WAY WORK EQUIPMENT

(For Report, see pp. 157–203)

Mr. C. R. Knowles (Illinois Central):—The report of Committee XXVII—Maintenance of Way Work Equipment, appears on pages 157 to 203 inclusive of Bulletin 381. This report includes a discussion of rail grinders, a review of the development of grinders for finishing rail ends, frogs and switches, together with a discussion of specifications for grinding wheels and a safety code for their use. There is also included a discussion on the selection and training of operators of work equipment, and a discussion of concrete mixing and handling equipment, and a manual for the care and operation of work equipment.

The Committee reports progress on Assignments 4, 5, 9, 10, 12 and 13. In common with the other committees, our Committee have made extensive revisions of material in the Manual and Manual Supplements, which have been revised and brought up to date. These revisions include the elimination of 75 definitions, the inclusion of certain material formerly included in the Manual chapter of Committee XXI, and the elimination or revision of certain other portions of Manual material as indicated in the report on page 158.

It is moved that the revisions as made by the Committee be adopted by the Association.

The President:—It is moved and seconded that the revisions as recommended by the Committee be approved for printing in the Manual.

(The motion was put to vote and carried.)

Chairman C. R. Knowles:—The Committee reports progress on Standardization of Parts and Accessories for Railway Maintenance Motor Cars, page 159. This is a progress report and is submitted as information.

The President:—It will be so received.

Chairman C. R. Knowles:—The report of the Sub-Committee on Track Grinders appears on page 161. The Chairman of that Sub-Committee is Mr. Faries, whom you heard speak last night. He is not present and I will present the report.

This report includes a review of the development in grinders now used, both electric and gas, and covers the improvements in various types of grinders. It appears on page 161. The report is submitted as information.

The President:—It will be so received.

Chairman C. R. Knowles:—On page 170 is a report on the "Selection and Training of Maintainers and Operators of Work Equipment," which is also submitted as information.

The President:—It also will be so received.

Chairman C. R. Knowles:—Appendix E on page 173 covers "Concrete Mixing and Concrete Handling Machinery." This is a comprehensive report on the various types of equipment used for mixing and handling concrete, and is also presented as information.

The President:—It will be so received.

Chairman C. R. Knowles:—Appendix F covers the Manual of Instructions for the operators of work equipment. Although the Committee are asking that the subject be dropped for the present, this report is not presented as a complete report by any means. It is fully realized that the report is not final nor complete, so please bear that in mind in taking action on this particular subject.

Appendix F is submitted as information with the recommendation that the subject be discontinued for the present.

Mr. W. A. Radspinner (Chesapeake & Ohio):—I realize what was said about the action to be taken on Appendix F. However, some of the things written into this report right now are things that I should like to take exception to on the floor of the convention.

On page 181, under "Care of Machine," the last sentence, paragraph 6, recommends the use of kerosene for cleaning purposes. All the refining companies now manufacture a high flash solvent for cleaning purposes which is much safer than kerosene.

On page 182, under "Gasoline Engines," paragraph 18, it is recommended that approved cans should be used for filling gasoline tanks, and in the next sentence it refers to the nozzle for gasoline hose. I have never seen any approved gasoline filling can that could be handled by a man that had a rubber hose and nozzle on it. It is my recommendation that the filling can be described as an underwriters' approved gasoline filling can with a flexible pouring spout. I think there would not be as much danger from the static spark in filling with this spout with the spout inserted in the tank as there would be in trying to pour it from the can and spilling it all over the outside of the tank.

On page 186, paragraph 34, it is stated that a leak in the field may be repaired by soldering. This should not be permitted, because a tank which has been filled up with such a volatile liquid as gasoline should be cleaned out with steam before any soldering is done, and that is not available in the field. I know of one case where a man tried this and they picked his head up in one place and his body in another. While it may not be possible to standardize on gasoline tanks for their location, I do think that it is possible they should not be mounted over the engine, and that care should be used in running a gasoline fuel line to the motor. Some of the cars exhibited at the Coliseum have long runs of fuel lines, more or less indifferently braced, and only one gasoline tank that I saw had an underwriters' approved filling vent on it. Some had the exhaust about 6 inches from the filling opening, the supposition being that the tank would not be filled while the motor was running. That may be true, but you can gamble on it that they would not wait until that red hot exhaust pipe cools off, and that is about the biggest hazard that you can have.

Chairman C. R. Knowles:—The remarks of the speaker will be given consideration by the Committee.

The President:—Are there any further suggestions?

Chairman C. R. Knowles:—That completes our report.

The President:—I trust that during the year the members of this Association will carefully review the material which has just been presented as information. Any contributions on the subject will be gratefully received by the Committee. If you will send it to the Secretary of the Association, it will be promptly referred to the Committee Chairman. The Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON ECONOMICS OF RAILWAY LOCATION

(For Report, see pp. 103–111)

Mr. F. R. Layng (Bessemer & Lake Erie):—The Committee report will be found in Bulletin 381, starting on page 103. The Committee reports on two subjects, first, Appendix A, "Operating Data Essential to Establish Units for Making Line and Grade Revisions to Meet Operating Requirements." This Appendix follows on pages 104, 105, 106, 107, 108 and 109. This report is offered as information.

The President:—It will be so received.

Chairman F. R. Layng:—Appendix B, "Effect of Speeds in Excess of 75 Miles per Hour on the Economics of Railway Location." The report follows on pages 110 and 111. This is offered as information.

The President:—It will be so received.

Chairman F. R. Layng:—The Committee has nothing further to offer at this time.

The President:—In the light of the changes taking place it is possible there would be a better appraisal of the work of Committee XVI if considered from the standpoint of the "Economics of Railway Relocation" rather than "Location". Competition resulting from the development of other forms of transportation, together with the progressive advances in the science of rail transportation, is largely responsible for the demands upon the railways to further develop new and possibly as yet untried means for improving transportation services in ways that have not been anticipated by current operating experience in order that the railways may continue to provide, but at greatly increased speeds, safe, economical, and efficient transportation.

It must be evident to Railway Engineers generally that this will ultimately develop problems associated with grade and alinement which naturally come within the field of study by Committee XVI.

It is fortunate for the railways that among the membership of this Association there are many Engineers who are intimately acquainted with the scientific principles which must sooner or later be invoked to meet these complex problems.

As previously stated in the case of other committees reporting, I trust that members of this Association will aid Committee XVI. If they have any information or suggestions and will forward them during the year to the Secretary, the material will be thankfully received by the Committee.

The Committee is now excused with the thanks of the convention (Applause.)

DISCUSSION ON CLEARANCES

(For Report, see pp. 291–305)

Mr. A. R. Wilson (Pennsylvania):—The report of the Committee will be found in Bulletin 382, page 291. It consists in revision of the Manual, and progress report on the second assignment to the Committee, which covers clearances for switch stands, water towers, tanks, etc.

In the portion with reference to the revision of the Manual, briefly, the question of clearances was started in 1914 by the Committee on Maintenance of the former American Railway Association. The present Committee on Clearances of the AREA was formed in 1922. The Committee in making its report this year believes it desirable to assemble all diagrams now appearing in the Manual so that same could be published in a separate bulletin and be readily available for railroad officers having use for such information. These diagrams covering the Committee report will be referred to as Fig. 1 to 14 inclusive. It is the recommendation that they be adopted and published in the Manual.

I will refer to the diagrams individually and, with the President's consent, discuss each diagram and ask for its adoption following discussion of that particular diagram. In addition to the diagram, there are a number of paragraphs which accompany them. I will read those paragraphs at the present time.

(a) The clearances on straight track shall not be less than those shown.

(b) On curved track the clearances shall be increased to allow for the overhang and the tilting of a car 85 ft. long, 60 ft. between centers of trucks and 14 ft. high.

In the paragraph just read there is a revision from that now appearing in the Manual, namely, the length of car has been changed from 80 ft. to 85 ft.

(c) The superelevation of the outer rail being in accordance with the recommended practice of the American Railway Engineering Association.

(d) The distance from top of rail to top of ties shall be taken as 8 inches.

The note following these paragraphs may be changed depending upon the action of the convention in respect of the figures.

The note reads as written: "Note. Paragraphs (a), (b), (c) and (d) apply to Figures 1 to 9 inclusive. Paragraph (e) applies to Figures 1 to 12 inclusive."

Fig. 1, which is a Clearance Diagram for Bridges, is identical with diagram previously submitted by this Committee and identical with diagram included in the Specifications for Steel Bridges as presented by Committee XV and adopted by the Association. The note on the bottom reading, "For Permanent Structures other than Bridges and Tunnels, see Fig. 5," may or may not remain, depending upon the action of the convention respecting Fig. 5.

I move that this Fig. 1 be adopted and printed in the Manual as suggested, with the understanding that the note will be corrected according to the action of the convention.

The President:—It is moved and seconded that Fig. 1, with the correction as now recommended by the Committee, be adopted for printing in the Manual.

(The question was put to vote and carried.)

Chairman A. R. Wilson:—Fig. 2, Clearance Diagram for Turntables. This is identical with the diagram that now appears in the Manual as submitted by Committee XV and is included in their specifications for turntables. I move that Fig. 2 be adopted.

(The motion was regularly seconded, put to vote and carried.)

Fig. 3 and 4, Clearance Diagram for Single Track Tunnel and Clearance Diagram for Double Track Tunnel. Last year this Committee presented a diagram which was entitled, "Clearance Diagram for Bridges and Tunnels." The Committee—I believe the Roadway Committee, which has charge of the diagrams for tunnels—called our attention to the fact that the bridge diagram did not entirely cover the tunnel diagram, and rather than have either of them changed, both of which have been used for a number of years, we concluded to separate the diagrams for the single and the double track tunnel, which are now presented in Fig. 3 and 4. This will explain somewhat the comment of the Masonry Committee yesterday when they said they could hardly keep up with the Clearance Committee and its diagrams. The reference made to the note at the bottom of Fig. 1 will apply to Fig. 3 and 4, if Fig. 5 is not adopted. Otherwise this note may change.

I move that Fig. 3 and 4 be approved for adoption with revision as to the note.

The President:—It is moved and seconded that subject to the qualification stated by the Chairman, the tunnel diagrams, Fig. 3 and 4, be adopted for inclusion in the Manual.

(The motion was put to vote and carried.)

Chairman A. R. Wilson:—Fig. 5, Clearance Diagram for Permanent Structures Adjacent to Main Tracks. This is a new diagram and is presented for the purpose of securing a minimum distance from the center of track to fixed structures, such as bridge abutments, piers, walls and permanent buildings, in order to provide a safe distance for railroad employees between the track and such structures.

The Committee received several criticisms of this diagram. Strange to say, the criticism received from our Western friends, where we think ample space can be provided, was to make this 10 ft. minimum 8 ft. We received a criticism this morning from an Eastern railroad. They want to make this distance 14 ft. So we have a variation in the dimension and recommend the 10 ft. minimum distance from center of track to the side or line of permanent structures. There is no trouble in securing the 10 ft. minimum in the states of Pennsylvania, New Jersey, New York, Maryland, Delaware or Virginia where congestion exists.

I move that Fig. 5 be adopted and printed in the Manual.

The President:—It is moved and seconded that Fig. 5 be adopted for printing in the Manual. All those in favor will signify by saying "aye."

Mr. Geo. S. Fanning (Erie):—I should like an opportunity to say something about this. I do not particularly want it to get railroaded.

This diagram will be used chiefly in connection with overhead highway bridges. For this use we believe it to be very detrimental to the railroads. The necessity for greater clearances than we require on railroad bridges, as shown in Diagram 1, arises from two causes: First, the safety of railroad employees, and second, drainage. Diagram 1 provides safe clearance for employees on the top or sides of equipment. For those on the ground footwalks can be provided outside of the truss if necessary. This is not possible with a solid abutment alongside of the track, so we propose to provide additional width equivalent to the form of the standard embankment. On our own road we use 11 ft. side clearance, in cases where no side ditch is required. Where there is drainage to be taken care of, we require that the ditch be spanned also to avoid forcing the drainage into the roadbed. But we often have to take less where there are extraordinary elements of cost. For piers between tracks we have on occasion used the standard railroad bridge clearances; ditches can be carried through the structure in pipes or back of piers. So our side clearances vary fom 8 ft. to 15 ft., depending upon the conditions at each stucture. The minimum of 10 ft. on Diagram 5 is so high that it is apt to be required as a maximum, which we should avoid. I therefore question the desirability of having any standard diagram for this purpose.

Mr. S. L. Wonson (Missouri Pacific):—Will the Committee please tell us how or why it decided on the particular figure of 10 feet? I presume it is not a question of adding up all the votes and taking an average, but for any figure there were certain reasons for its adoption and certain elements that had to be provided for. Will the Committee please tell us just what that 10 feet provides for and what it does not provide for?

Chairman A. R. Wilson:—In the opinion of the Committee it was felt that this figure would give ample clearance on equipment alongside of bridge abutments, piers or retaining walls for the safety of the railroad employees. It does not provide enough distance for track drainage.

Mr. R. C. Bardwell (Chesapeake & Ohio):—I would raise a question in this connection. I should like to have a little further explanation as to whether this clearance diagram for permanent structures also includes water service structures. I am referring paticularly to water columns. In looking over the clearance diagrams as presented by this Committee, there is, I find, no place under them for the water columns ordinarily used on a great many railroads. If this clearance diagram, Fig. 5, is to be taken and used for water column installations, it will mean arranging for distance between track centers of 23 ft., which is unreasonable and impractical due to excessive length of spout which would be required. If water columns are installed under clearance diagram, Fig. 1, it would mean arranging for 19 ft. track centers. On a great many railroads, the standard setting for water columns requires only 17 ft. track centers which appears to provide perfectly safe clearance. To change this to 19 ft. track centers would result in an enormous expense in the aggregate. Before standard clearance diagrams are officially adopted, information should be given showing definitely what provision is to be made for water service structures.

Chairman A. R. Wilson:—The reference to the progress report of the Committee included that further study would be made with reference to water columns. It is the intention of the Committee that this diagram cover only those items mentioned in the sidenote, which reads, "For overhead bridge abutments, piers, retaining walls and permanent buildings."

Mr. R. C. Bardwell:—What about that notation, "Line of Permanent Structures"?

Chairman A. R. Wilson:—That line which reads, "Line of Permanent Structures," bears an arrow pointing to it from the note I just read.

The President:—The question is on the adoption of the diagram shown in Fig. 5 and its publication in the Manual. Meanwhile doubt has been expressed as to the desirability of publishing the diagram as Manual material at this time. The question is on the original motion. All those in favor will signify by saying "aye"; contrary-minded, "no".

The Chair is in doubt. The "ayes" will rise You can be seated now. Let's see what the "noes" have to say about it.

(The motion was put to vote and lost.)

The President:—The diagram will be referred back to the Committee.

Chairman A. R. Wilson:—Then that will automatically eliminate the footnote on the bottom of Fig. 1, Fig. 3 and Fig. 4.

Mr. Geo. S. Fanning:—In that connection I should like to suggest that on Diagram 1 the title be changed to read, "Clearance Diagram for Railroad Bridges," so that we will not have that thrust upon us always as something to be used for overhead bridges.

The President:—The Committee accepts the suggestion of Mr. Fanning and correction will accordingly be made.

Chairman A. R. Wilson:—Fig. 6, Clearance Diagram for Buildings and Sheds, and the Clearance Diagram for Warehouse and Engine House Doors, shown in Fig. 7, are identical with those approved by the convention last year, and by the action of the convention just taken, the note appearing in the upper left-hand corner of Fig. 6 will be omitted. I move these two diagrams be approved.

The President:—It is moved and seconded that the two diagrams reported by the Chairman be approved for printing in the Manual.

Mr. S. L. Wonson:—Could I ask, to clear up an uncertainty there, as to what the distinction in the mind of the Committee is between buildings and permanent structures, or between buildings and permanent buildings. That is going back, if I may, regardless of previous action, to the diagram of Fig. 5 for permanent structures, which includes permanent buildings, and to this diagram of Fig. 6 for buildings. What is the nature of the building the Committee had in mind in Fig. 6?

Chairman A. R. Wilson:—Fig. 6 covers sidetracks.

Mr. S. L. Wonson:—Sidetracks only?

Chairman A. R. Wilson:—Alongside of main tracks, if necessary.

Mr. Geo. S. Fanning:—I suggest that the title of that diagram could be improved by calling it "Clearance Diagram for Buildings Adjacent to Sidetracks."

Chairman A. R. Wilson:—I agree.

The President:—The Committee accepts the suggestion of Mr. Fanning.

If there are no further questions, the motion is on the adoption of the recommendations of the Committee.

(The motion was put to vote and carried.)

Chairman A. R. Wilson:—Fig. 7, Clearance Diagram for Warehouse and Enginehouse Doors. There are no changes in this diagram from that now appearing in the Manual. I move it be adopted.

The President:—It is moved and seconded that the diagram reported by the Chairman be accepted and adopted for printing in the Manual.

(The question was put to vote and carried.)

Chairman A. R. Wilson:—Fig. 8, Clearance Diagrams for Platforms. There is a change in the diagram from 4 ft., I think, to the figure of 3 ft., 7 in., the height of platforms for sidetracks only. This will make the diagram coincide with similar information as adopted by the Society of Terminal Engineers in the City of New York. I move the adoption of Fig. 8.

The President:—The Committee recommends the approval of Diagram No. 8.

(The motion was put to vote and carried.)

Chairman A. R. Wilson:—Fig. 9. No change in this diagram from that now appearing in the Manual and I move its adoption.

(The motion was regularly seconded, put to vote and carried.)

Fig. 10, 11 and 12 apply to various highway lane arrangements and cover the horizontal and vertical clearance for railroad bridges over the highway. These diagrams as presented are identical with those appearing in the specifications of the State Highway Officials' Association publication. They are a revision over those now appearing in our Manual in that the clearance is on a direct angular corner rather than being cut by a diagonal line. The action of the convention yesterday in approving the recommendation of Committee XV covering the removal from our Manual of all specifications of overhead bridges may affect your discussion and decision on the adoption of these three diagrams. Inasmuch as all of these diagrams are presented for the purpose of gathering together in one pamphlet diagrams covering clearances, it would seem desirable to include these three diagrams in such a pamphlet.

I move their adoption.

Mr. Geo. S. Fanning:—If these are identical with those adopted by the State Highway Officials, there seems to be no reason for the railroads to adopt them. We can use the Highway Officials' diagrams to convince them, but it has proved unfortunate when they have used our diagrams to convince us. I particularly refer to the 16 ft. and 14 ft. overhead clearances shown on these diagrams. We have not built any 16 ft. overhead clearances in I do not know how long, not even for trolley cars. 14 ft. is entirely ample. Still we here offer to take 16 ft. as standard. So far as 14 ft. is concerned, we all have many structures with less clearance, some of them of recent construction, which would be damned out of our own mouths were we to adopt these diagrams. There are occasions when the costs to get clearances in excess of 13 ft. are entirely unwarranted. I do not believe that these three diagrams should be adopted.

The President:—The diagrams as presented call for 16 ft. clearance. Mr. Fanning objects, he believes that 14 ft. clearance is sufficient.

Chairman A. R. Wilson:—I think the real argument is whether we should present these diagrams at all.

Mr. Geo. S. Fanning:—Right.

Chairman A. R. Wilson:—That is the issue.

The President:—The Chair is in doubt as to the wishes of the convention.

Mr. Geo. S. Fanning:—Unless there is a motion before the house (I do not know whether there is or not)—I move that these diagrams be deleted.

Mr. R. C. Bardwell:—As Committee Chairman, I believe, we received instructions from the Board of Direction that where the same information was available in standard works of other associations there was no place for it in the AREA Manual other than by reference. Under that ruling, it would appear to me that the adoption of these three diagrams is superfluous in this instance.

The President:—The question is on the adoption of the diagrams for printing in the Manual. If there are no further questions, all those in favor will signify by saying "aye." (None) All those opposed will say "no." It is quite evident that the "noes" have it.

Chairman A. R. Wilson:—It sounds that way. Fig. 13, Equipment Diagram Unrestricted. This outline of equipment is identical with what has been known for some time as Plate B. It was developed by the Committee on Car Construction in 1920 and has had somewhat of an approval by this Association. It seems desirable at this time to present it formally for adoption so that the Car Construction Committee will have definite information as to what outlines equipment may be designed. Before I make the motion I think it is desirable to make some reference to Fig. 14. Apparently there is some difference, maybe not of opinion but of understanding, as to the words "restricted" and "unrestricted." The Mechanical Division work on the theory and understanding that a restricted diagram means one under which a car built with those dimensions cannot move in all territories. Fig. 13 would permit a car to be built to this outline which can be moved generally in all territories on all railroads, this being developed as a result of a questionnaire which this Committee developed several years ago.

With that information, I move adoption of Fig. 13.

The President:—It is moved and seconded that Diagram 13 be adopted for printing in the Manual.

(The question was put to vote and carried.)

Chairman A. R. Wilson:—In the studies of the questionnaire, information was also developed which indicated that every railroad in the United States had some large equipment, that large equipment, however, could be confined to its own rail lines. It also is the desire for the maximum size of equipment that can be handled in normal routes and over the main lines of our railroads. Such a diagram has been prepared and is submitted as Fig. 14, which indicates equipment built within this diagram can be handled in regular service. The railroads themselves are building cars larger than this diagram. Usually the routes of such equipment can be controlled.

I move that Fig. 14 be adopted.

The President:—It is moved and seconded that Fig. 14 be adopted for printing in the Manual.

(The motion was put to vote and carried.)

Chairman A. R. Wilson:—Returning to page 292, paragraph (2) is to be corrected according to the action of the convention just taken. It reads that these diagrams, including the paragraphs, "be submitted to the Association of American Railroads, with the recommendation that this data, with data developed by other Sections of the Engineering Division and the Telegraph and Telephone Section, be promulgated in a special pamphlet as the recommended practice of the Association of American Railroads for clearances."

This concludes the report of the Committee.

Mr. R. C. Bardwell:—Is it the idea to present this matter to the Association of American Railroads for adoption before it is complete?

Chairman A. R. Wilson:—I think, Mr. Bardwell, it would be better to present this now because it is going to take considerable time to develop and inasmuch as in the Railway Line Clearance bulletin information now appears covering the item which you have just mentioned. Until that is changed I assume that would still apply.

The President:—I have no desire to unduly influence the action of the convention but can assure it that there is a very urgent necessity for these diagrams. I have been advised that the Mechanical and the Transportation Divisions of the Association of American Railroads are hopeful that some formative action will be taken by this Association today, and I trust that the recommendations of Chairman Wilson will prevail. As no objection has been offered it will be taken as the will of this convention and the Committee recommendations will stand as approved as amended.

Mr. Wilson, you have been handling a matter of great importance to the railroads. I know something of the care and skill with which it has been conducted and the vast amount of work that you have put into the subject. The Committee and you have earned the thanks of this Association and are to be congratulated on the result of your work. You are now excused with additional thanks from the convention (Applause).

DISCUSSION ON BUILDINGS

(For Report, see pp. 275–290)

Mr. O. G. Wilbur (Baltimore & Ohio):—The report of Committee VI—Buildings, will be found in Bulletin 382, beginning on page 275.

Your Committee respectfully presents its report herewith on the following subjects:

On Subject 3, Influence of the Design of Buildings on Fire Insurance Rates, 5, Different Types of Paint and their Economical Selection, 7, Type of Foundation Best Suited for Railway Buildings, 9, Design of Small Cold Storage Plants for Railway Use, the Committee reports progress on these four subjects. Considerable work has been done on each of these reports and we expect to offer them next year for your consideration.

On Subject 8, Mill Type and Other Heavy Wood Construction for Railway Buildings, the report on this subject was submitted in 1935 as information and discussion was invited. There is no further report offered on this subject and the Committee recommends that it be discontinued.

On Subject 1, Revision of Manual, it is recommended that the material contained herein be adopted for publication.

The Committee recommends that the material now appearing in the Manual on page 264 under the caption, "Passenger Stations," be amended and revised as indicated on page 276 of Bulletin 382.

It recommends that the reference to grades for passenger ramps, shown on page 266 of the Manual, be revised as shown on page 276 of Bulletin 382, under the caption, "Stairways and Ramps."

It recommends that the paragraph on "Scales—General," appearing on page 271 of the Manual, be revised as shown on page 276 of Bulletin 382, under the caption, "Scales."

It recommends that the material on "Oil Houses" on pages 274 and 275 in the Manual be eliminated. This Committee revised and consolidated the material in the Manual, originally prepared by it, with that on pages 1486 and 1487, prepared by Committee XXIII, into one unit of text. This was submitted to Committee XXIII and a further revised text was developed that was acceptable to both committees. This revision will be presented by Committee XXIII for your action.

It is recommended that the Manual material on "Rest Houses" and "Section Tool Houses," appearing on pages 275 and 277, respectively, be changed as recommended on pages 276 and 277 under the same headings.

It recommends that an Index of Specifications for Buildings for Railway Purposes be inserted in the Manual immediately preceding Section 1 of the specifications. This Index is found on page 277 of Bulletin 382.

In that connection, since the printing of the Bulletin we have decided to make one change and we should like to add another item on a new line, following the words "Concrete Architectural Stone," the item "Concrete," and refer to Section 4.

On pages 278 to 281 inclusive recommendations are made which cover revisions in specifications now appearing in the Manual for cement, sand, lime and mortar, under Sections 3, 5, 6, 7, 8, 9 and 30-B.

It also recommends that sketches for plumbing fixtures appearing on pages 381 to 401 in the Manual be omitted in its next printing, and the text on page 376 be revised as stated on page 281 of Bulletin 382, under the caption, "Plumbing."

I move the adoption of these various recommended changes in the Manual.

The President:—It is moved and seconded that the changes recommended by the Committee on Buildings be accepted and printed in the Manual.

(The motion was put to vote and carried.)

Vice-Chairman O. G. Wilbur:—Subject 2, "Preparation of Specifications for Railway Buildings," is found in Appendix B. The recommendation as printed in the Bulletin is incorrectly stated and should read as follows: "The Committee presents two sections of specifications for publication in the Manual and one section to be published in the Proceedings as information."

Mr. Judd, the Chairman of this Sub-Committee, will present this report.

Mr. F. R. Judd (Illinois Central):—The report of the Sub-Committee is found on page 281 of Bulletin 382 and we are now offering for publication or adoption in the Manual specifications known as "Section 30-F. Genuine Wrought Iron Chimneys—Welded."

This specification was published in the Proceeding last year as information and the Committee is now offering it for adoption in the Manual, and I move that the specification be adopted for Manual publication.

The President:—It is moved and seconded that the specification recommended by the Chairman of the Sub-Committee be accepted and printed in the Manual.

(The motion was put to vote and carried.)

Mr. F. R. Judd:—The Committee also offers for publication in the Manual specifications on built-up roofing known as "Section 10-D." These specifications cover Type D-1, "Asphalt Rag Felt and Asphalt (Smooth Surface) over Wood or Pre-Cast Units," and we also submit "Built-Up Roofing," Type D-2. That covers "Asphalt Rag Felt and Asphalt (Smooth Surface) over Homogeneous Roofs Cast in Place." These specifications were offered last year as information and published in Bulletin 373, and the Committee recommends that these specifications be adopted and published in the Manual, and I so move.

The President:—It is moved and seconded that the specifications as now presented be accepted and printed in the Manual.

(The motion was put to vote and carried.)

Mr. F. R. Judd:—The Committee offered as information last year a specification for the construction of reinforced brick chimneys. We received some discussion on this subject during the past year and are holding this for further discussion and criticism for the next year.

We are offering at this time a specification for Cement Grouted Macadam Pavements, Floors and Platforms, known as Section 26-C. This is offered as information with the hope that we will receive some criticism during the coming year and can then prepare the specification for final acceptance of the Association.

The President:—It will be so accepted and I trust that the request of the Committee will be borne in mind by the members of the Association.

Vice-Chairman O. G. Wilbur:—Subject 4 is found as Appendix C on page 287, Determination of the Destructible Value of Structures which can be Collected in Case of Fire.

I had expected our Sub-Committee Chairman, Mr. Copland, to present the report, and in his absence I will go on with it personally. This report, briefly, contains information which is of considerable value. It is a short report and rather than just scan over it and possibly miss some of its important features, I should like to hurriedly read the report.

(The Vice-Chairman read the complete report on Subject 4, Appendix C, pages 287 and 288 of Bulletin 382.)

This is offered as a progress report. The Committee invites your comment. We feel that the material in this report is Manual material and it will probably be offered next year as such.

The President:—It will be so received.

Vice-Chairman O. G. Wilbur:—Subject 6, Appendix D, Application of Stainless and Rust-Resisting Metals to Building Construction, is found on page 288. This subject has given our Committee considerable concern for several years. The application of metal and metal alloys which have stainless or rust-resisting qualities to a more or less degree, in building construction, covers a broad field. Such materials should be selected for their general merits for the particular use required, giving consideration to cost.

In this report the merits and application of lead, zinc, nickel, copper, brass, bronze, aluminum alloys, Monel metal and stainless steel have been discussed in a general way. The report is offered as information with the recommendation that the subject be discontinued.

The President:—It will be so received.

Vice-Chairman O. G. Wilbur:—That concludes the report of the Committee.

The President:—Mr. Wilbur, I want to congratulate you upon the report of the Committee as well as the excellent manner in which it has been presented. The Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON SHOPS AND LOCOMOTIVE TERMINALS

(For Report, see pp. 71–79)

Mr. J. M. Metcalf (Missouri–Kansas–Texas):—The report of Committee XXIII is printed in Bulletin 381, pages 71 to 79 inclusive. The Committee reports progress in study but submits no report on Subject 2, Welding Equipment.

It submits progress report as information and is asking for continuation of the study on Subject 3, Adaptation of Enginehouse, Shops and Engine Terminal Layouts for Handling Oil-Electric Locomotives and Rail Cars. The progress report is printed as Appendix B on page 73 of the Bulletin.

A progress report on Subject 4, Power Plants, is printed as Appendix C, on pages 74 to 77 of the Bulletin.

The Committee submits a report recommending revision of the Manual, which will be presented by Mr. L. P. Kimball, Chairman of the Sub-Committee.

Mr. L. P. Kimball (Baltimore & Ohio):—This report as the Chairman of the Buildings Committee has already indicated, is in the nature of a joint report of the two committees. At least they worked in collaboration.

The subject is the Oil House section of the Manual, and the recommendation of the Committee is contained in Appendix A, beginning on page 71. This material is intended to replace the material now appearing in the Manual as amended by Committee VI on pages 274 and 275 and by Committee XXIII on pages 1486 and 1487.

I wish at this time to make a slight correction. In the paragraph at the bottom of page 71, in the last line the word "high" in "high flashpoint oils" has been used in error. The word "high" should be changed to "low."

I move that the material as appearing in this Bulletin be adopted by the Association for publication in the Manual as indicated.

The President:—It is moved and seconded that the recommendation of the Committee be accepted and adopted, and it includes this additional material which has been also recommended for printing in the Manual.

(The motion was put to vote and carried.)

Chairman J. M. Metcalf:—The Committee presents as information a final report on "Car Wheel Shops," which will be presented by Mr. McBride, the Chairman of the Sub-Committee.

Mr. J. S. McBride (Chicago & Eastern Illinois):—The report on "Car Wheel Shops" is contained in Appendix D, starting at page 77. Your Committee in considering this subject was of the opinion that a study of a modern shop with illustrations showing how the problems of layout and design have been worked out in a particular case would be more valuable and helpful than an abstract discussion.

There is submitted a plan of a modern freight car shop layout of the C.&O. at Russel, Kentucky, showing the location of the wheel shop with relation to other facilities, and a plan of the car wheel shop itself with its machinery and equipment. The report describes the operation of the wheel shop and the method of handling wheels through it both for the car shop and for outside points. The report is submitted as information.

The President:—It will be so received.

Chairman J. M. Metcalf:—That concludes the report of the Committee.

The President:—Mr. Metcalf, you have a very fine Committee, with a splendid record, and the Board of Direction joins with me in the belief that even more important work will be accomplished by it in the future. Your Committee is now excused with the thanks of the convention (Applause).

DISCUSSION ON RULES AND ORGANIZATION

(For Report, see pp. 723–728)

Mr. E. H. Barnhart (Baltimore & Ohio):—The report of Committee XII—Rules and Organization, will be found in Bulletin 384, beginning at page 723.

The principal work of the Committee during the year consisted of revision of the Manual. In line with the request of the Committee on Manual, the subject-matter was thoroughly studied and changes are indicated in Appendix A, beginning on page 723. In recommending elimination of material obtained from or through Sections of the AAR, the Committee has done so in the interest of avoiding duplications but feels that reference should be made in the AREA Manual indicating just where such material may be found. So the Committee is recommending to the Association the elimination of such operating rules as are found in the Standard Code. We also suggest dropping Signal and Telegraph and Telephone rules as are found in the manuals of the Signal and T.&T. Sections respectively.

The revision of the rules covering handling explosives has been approved by the Bureau of Explosives of the AAR.

Since the work of revision of the Manual was divided up into small sub-committees to handle each part of the Manual, the revisions are listed in numerical order and I will read the general heading and the revisions proposed.

At the bottom of page 723, the column on the left-hand side shows the present, or reference to the present Manual. The column on the right-hand side is shown the proposed action.

"Table of Contents"—eliminate.

"General Notice"—eliminate, and substitute "See Standard Code, AAR."

"General Rules"—Insert after "General Rules": "See also Standard Code, AAR." Eliminate Rules 1, 3, 5, 6. Eliminate the first two sentences of Rule 2 and renumber Rule 1. Rule 14, eliminate and substitute: "Employees must be familiar with the rules and regulations in the current timetable." The balance of the section has to do with renumbering of the remaining rules. The rules eliminated appear in the other Sections' Manual or Standard Code.

At the top of page 724, "Operating Rules." Eliminate all subject-matter under title. Insert after title, "See also Standard Code, AAR." Substitute two rules: "100. When an employee does not have access to a standard clock, he must compare his watch with that of an employee who has made such comparison.

"101. Maintenance of Way employees must not disturb burning fuses on or near the track placed there by trainmen." These two rules do not appear in the Standard Code.

"Use of Signals." Eliminate all subject-matter under title and substitute following: Under title insert, "See also Standard Code, AAR."

"150. Watchmen stationed at public crossings at grade must use proper signals when necessary to stop trains. They will use stop signals to control highway traffic."

The Committee in studying the Rules for Operation of Motor, Hand, Velocipede and Push Cars, as shown in the 1929 Manual on page 806, recommends the elimination of Rule 263 and the substitution of the following: "Motor, hand and velocipede cars are to be used only for transporting workmen and tools. Heavy material must not be carried on them, except in emergency." Eliminate Rule 264, as it is a duplication. We recommend the deletion of Rule 270 and the substitution of the following, which has to do primarily with the change in allowable speeds of motor cars: "270. Cars must not exceed a speed of 8 miles per hour when passing through stations or yards, over switches or through interlocking, over frogs, railroad, highway or crossings at grade. At all other points, handcars are restricted to 10 miles per hour and motor cars as follows: —Gang cars without trailers, 20 mph; gang cars with trailers, 15 mph; light inspection cars center load, 20 mph; light inspection cars side load, 15 mph. Heavy duty inspection cars assigned to Division officers weighing 1500 lb. or more and equipped with axles 2 in. or more in diameter, 30 mph. Cars must be stopped, when practicable, during passage of a train on an adjacent track."

We recommend a change of the second sentence in Rule 276 as follows: "When they cannot be removed from the track to clear an approaching train, they must be protected as required by Standard Code, AAR."

We recommend the change of Rule 420, page 816 of the Manual as follows: "Supervisors of water service report to and receive instructions from the Division Engineer."

The change consists in providing for definite organization.

Eliminate Rule 455 page 817 and substitute the following rule. "455. Pumpers shall keep such records on prescribed forms as may be required."

Page 817, Rule 470. This change is made for the same reason given for changing Rule 420.

"Supervisors of Signals," page 819 of the Manual. We recommend the elimination of the reference under these rules as follows: Eliminate "(A Rule preceded by * is a rule of Signal Section, ARA.)" and such references on each of the rules following.

Eliminate the rules for "Duties of Telegraph and Telephone Officers," Manual pages 823 and 825, and in the Supplement to the Manual, Bulletin 378, as this information is contained in the T.&T. Section Manual. The titles are to be grouped and a reference shown after them "See T.&T. Section Manual, AAR."

The change indicated in Rule 706, page 828 of the Manual, is shown in the report.

707, the last sentence reads: "Ties shall be adzed only when necessary to obtain a full bearing under rail or plate." Proposed 707: "Ties shall be adzed only to the extent necessary to obtain a sufficient bearing under rail or plate."

These changes are approved by the Tie Committee.

The President:—Let me suggest that you just read the rule number and then pause, and if there is any objection I will ask the floor to state it.

Chairman E. H. Barnhart:—New Rule 785. "Preparatory to placing ballast, the roadbed must be widened, if necessary, to bring it to the adopted standard width."

Rule 797, proposed: "In gravel, stone, chatts, chert, slag and cinders, the ties must be tamped from 15 inches inside the rail out to the ends," etc., the change being the elimination of burnt clay ballast.

We recommend the elimination of Rule 880. There is a slight error in the print. Renumber Rule 881 instead of as it is shown. Then the new rule to be known as 881: "Flangeways must be kept clean of rubbish, snow, ice, and other obstructions. Defective crossing plan must be repaired."

Under "Signals and Interlocking," we recommend the elimination of the rules starting at 900, and a note be added: "For maintenance of signals and interlocking, see Manual, Signal Section, AAR."

The balance of the revision of the rules refers to the handling of explosives. I will read the new rules which have been approved by the Bureau of Explosives.

"2025. Danger signs must be conspicuously placed on all buildings and magazines, above the roof, if practicable, in which explosives are stored.

"2026. Dynamite, powder and other explosives shall be stored in fireproof magazines located at a safe distance from the company buildings, or buildings and property of others in accordance with the law, where they are not liable to be interfered with. In states where no laws are in effect, the American Table of Distances should be used.

"2028. Fuses and blasting caps must in no case be stored in the same building with explosives.

"2029. Any employee assigned to the handling of explosives must satisfy the Supervisor of his qualifications and previous experience in their use.

"2031. Under no circumstances may an employee permit dynamite, blasting caps or other explosives," changing the words to "blasting caps," instead of the words shown on the left-hand side.

"2033. Some dynamites are likely to freeze when the temperature falls below 50 deg. Fahr.," instead of the text shown on the left-hand side.

"2034. Dynamite may be thawed by using an approved kettle."

"2050. All gasolines vaporize rapidly in hot weather."

2051. Last sentence. "Lighted matches, pipes or cigarettes and fires must be kept away from these tanks."

"2053. Fuses, torpedoes, or matches must be kept separated in storage. Only containers provided for their protection must be used for transportation.

"2054. Do not use water on an oil fire. Use foam, carbon dioxide or carbon tetrachloride fire extinguishers, if available, otherwise smother with steam, wet blankets or dry earth."

Eliminate the wording shown on page 868 as the charts to which reference is made, were eliminated from the Manual at last year's convention.

The Committee is offering a chart showing the maintenance of way divisional organization at the bottom of page 726.

I move adoption of the revisions.

The President:—It is moved and seconded that the recommendations of the Committee as read be accepted and adopted for printing in the Manual. Are there any questions?

Mr. H. M. Stout (Northern Pacific):—I should like to refer back to the beginning, page 723, and to the changes mentioned on the top of page 724. In each of those there is a statement "eliminate and substitute," and "See Standard Code, AAR," or "See also Standard Code, AAR."

I do not have the text of the Manual with me, but it would seem, just from the information contained in the report, that possibly the word "also" is not only superfluous but really out of order as it gives a wrong meaning. This is merely a substitution of a reference to the AAR regulations rather than in addition to what you are retaining in the Manual.

Chairman E. H. Barnhart:—There are 23 rules under the division "Operating Rules." We are eliminating 21 rules which appear word for word in the Standard Code. I think the word "also" is correct.

Mr. H. M. Stout:—In your statement you say, "Eliminate all subject-matter under title," and then insert, "See also Standard Code," and so on.

Chairman E. H. Barnhart:—I do not know how to answer it except to say that the present Manual contains 23 rules, 21 of which are in the Standard Code. They were simply repeated. We want reference made to where these rules can be found. For that reason we desire the words, "See also Standard Code" shown under the title, "Operating Rules." Following that we would reprint or put in the revised rules shown under the new numbers, 100 and 101, shown at the top of page 724. I do not know whether that answers your question or not.

The President:—Is there any further question? If not, the question on the adoption of the rules as recommended by the Committee. Are you ready for the question?

(The question was put to vote and carried.)

Chairman E. H. Barnhart:—The second subject assigned to the Committee covering the preparation of rules for the "Maintenance of Terminal Structures other than Buildings." We report progress and study but have no report to offer this year.

The next subject is "Protection of Treated Ties and Timber." The Committee reports progress, but due to not obtaining entire collaboration with these three Committees, we have no report this year.

The third subject, "Rules for Fire Protection, collaborating with Committee XIII —Water Service, Fire Protection and Sanitation," is presented in Appendix B, page 727, as information. These have been approved by Committee XIII. We should like to have any criticisms or corrections or suggestions that any members of the Association have to offer. If they will forward them to the Secretary, we will receive them.

The President:—It will be so received.

Chairman E. H. Barnhart:—That completes the report.

The President:—Mr. Barnhart, your Committee has been working under somewhat difficult and unusual conditions which have required loyalty and patience along with your efforts. In addition, you came before the convention in its closing hours. Altogether it was not so easy for you. The Committee is now excused with the thanks of the convention (Applause).

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